DUST SUPPRESSANT STUDY

MARCH 1988

Environment Ontario

Jim Bradley
Minister

ISBN: 0-7729-4349-4

DUST SUPPRESSANT STUDY

Report prepared for:
Waste Management Branch

Report prepared by:
Acres International Limited

MARCH 1988
REPRINTED JUNE 1989

RECYCLABLE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1 - INTRODUCTION

1 - INTRODUCTION

A variety of materials are used within Ontario to control dust on unsealed roads. Typically, these materials are selected by the responsible municipality on the basis of cost including application cost as well as effectiveness. Particularly where materials have a short effective time, cost of transportation can be very important and local sources of a suitable low or zero cost product are very desirable. For some time concerns have been expressed about the long-term environmental effects of road spraying of materials such as waste oil with a known potential for environmental damage.

The study described in this report was commissioned by the Ontario Ministry of the Environment to examine the effectiveness and impact on the adjacent environment of a variety of substances that are used at present or might be appropriate in the future. Major components of this study were as follows.

1 - A review of the available information and regulations regarding dust suppressants.

2 - Selection of particular suppressants to be evaluated in the field study and selection of sites where these suppressants had been used exclusively for several years.

3 - Dustfall monitoring at the six sites during the summer months.

4 - Analyze road surfaces, roadside soil and vegetation, background soil and the suppressants themselves to investigate the significance and fate of major components if the suppressants to the environment.

5 - Measure vehicle-generated dust using fixed and mobile samplers while a vehicle was driven along the test section of road.

2 - BACKGROUND REVIEW

2 - BACKGROUND REVIEW

2.1 - Methodology

An extensive retrieval and review of relevant information was carried out at the beginning of the study. To ensure that the study remained focused on the area of interest, semipermanent aliphatic petroleum products were excluded from the review. Both literature searching and agency contact were used to identify relevant information.

Twenty-one environmental and transportation agencies were contacted in Canada and the United States (see Appendix A) with the objective of determining

(a) existing and planned policy, legislation and guidelines pertaining to road dust control

(b) the rationale for any policies, legislation and guidelines

(c) road dust control studies undertaken within each jurisdiction contacted, especially pertaining to performance, cost and environmental impacts of materials tested.

In addition, the following computerized data bases were searched on the subject of road dust control.

Canada

ELIAS	(Environment Canada Library)
IEC	(Directory of Federally Supported Research in Universities)
NRC	(National Research Council of Canada)
OON	(Canada Institute for Scientific and Technical Information - Current Catalog

OOT	(Canadian Transportation Documentation System - Transport Canada)
<u>U.S.</u>	
EI	(Engineering Index)
ENVIROLINE	(Environment Information Center, New York)
ENVIROBIB	(Environmental Studies Institute, Santa Barbara, California)
NTIS	(National Technical Information Service)
TRIS	(Transportation Research Information Service)

2.2 - Policies, Regulations, and Guidelines in Other Jurisdictions

2.2.1 - Canada

Eighteen agencies in Canada were contacted (see Appendix A), to determine existing policy with regard to dust control on unpaved roads. The results are summarized in Table 2.1. On a federal basis, the Chlorobiphenyl Regulations No. 3 (Release) under Canada's Environmental Contaminants Act state that a maximum of 5 ppm chlorobiphenyls (PCBs) may be applied to a road surface in any geographical area of Canada except where the Fisheries Act applies.

As of February 1987, Ontario and Quebec were the only provinces in Canada with legislation or guidelines pertaining specifically to dust control on roads. Quebec has banned the use of new and used oil for dust control primarily because of concern with PCBs. Tests conducted on used oils in Quebec showed PCB levels ranging from very high to negligible. The Quebec government decided that control would be difficult if they allowed the use of some oils on roads. Therefore, to achieve complete control of the situation, and because more environmentally acceptable substitutes were available, e.g. calcium chloride (Environment Quebec

TABLE 2.1

CANADIAN ENVIRONMENTAL LEGISLATION AND POLICIES PERTAINING TO ROAD DUST CONTROL MATERIALS

Jurisdiction	Act/Guideline	Regulation	Description
Federal	Environmental Contaminants Act	Chlorobiphenyl Regulations No. 3 (Release)	The maximum concentration of chlorobiphenyls in the course of an application to a road surface is 5 ppm in any geographical area of Canada except waters where the Fisheries Act applies.
Ontario	Environmental Protection Act	Waste Management PCBs Regulation (Reg. 11/82)	Liquids used or proposed for road oiling, containing PCBs at more than 5 ppm must be reported to the Director of the Waste Management Branch, MOE.
	Environmental Protection Act Part V	Waste Management Reg. 309	A certificate of approval is required prior to use of a dust suppressant.
	Guideline for the Treatment and Disposal of Liquid Industrial Wastes in Ontario		Recommends road oiling as an optional method for waste oil disposal
Quebec	Environment Quality Act	Hazardous Waste Regulation	Division II - General, Section 9. No person shall spread dust control oil.
		Regulation Respecting Pulp and Paper Mills	Division V. Pulp and Paper Waste Management. Section 31. Pulp and paper mill waste must be eliminated by landfilling, recycling, pyrolysis or burning in a combustion apparatus or incinerator.
	Guide for the Storage of Hazardous Wastes and Management of Used Oil (1985)		P.16. It is forbidden to spread new or used oil for dust control purposes.

1987), the use of new and used oil for dust control was banned. Most other provinces have dust control covered generally under air and water quality regulations. However, two provinces (British Columbia and Nova Scotia) are preparing legislation that will limit the use of waste oil for road dust control. British Columbia is planning to implement a special waste management regulation in June, 1987. It is anticipated that waste oil will be recognized as a special waste and that maximum levels of contaminants (e.g. PCBs) will be specified. Contaminant levels are expected to be based on the existing practices of other provinces (e.g. Ontario) (BC Ministry of Environment, 1987).

The Nova Scotia Department of the Environment is planning a new waste oil regulation under the Dangerous Goods and Hazardous Wastes Management Act which they hope to have approved by July 1987. Although specific wording of the regulation has not been finalized, the Department of Environment will be recommending a ban on the use of waste oil as a dust suppressant due to its potential contamination. The Times Beach, Missouri incident involving a sludge-containing dioxin mixed with waste oil and used as a dust suppressant has been a major factor in the ban on waste oil (Nova Scotia Department of the Environment, 1987).

In Saskatchewan, there are no specific regulations pertaining to road dust control but there are guidelines for the use of waste oil for dust suppression (Appendix B). Saskatchewan Environment also requests specific information whenever dust suppressant projects are proposed (see Appendix B).

2.2.2 - U.S.A.

In New York State the use of waste oil for dust control on roads is prohibited under Section 10B of the New York State Highway Land and DOT Regulation 17 NYCRRI6I "Control of Dust". Road oiling is also prohibited under Section 173 of NY State's Navigation Law which deals with waterway pollutants.

California and Massachusetts also have their own regulations prohibiting the use of waste oils for road oiling. Other states (e.g. Oklahoma) permit road oiling on a case-by-case basis. Vermont currently allows the use of waste oil as a road dust suppressant provided certain specifications are met. The waste oil must have no detectable concentrations, that is zero ppm (Reid, 1988) of PCBs, must contain less than 50 ppm total organic halogens, less than 1000 ppm total inorganic chloride, and less than 200 ppm lead; must have a flash point higher than 140 deg F; and the net heat of combustion must be equal to or greater than 8000 Btu per pound. The applicator of such oil must test it and notify the Vermont Agency of Environmental Conservation about the operation dates, location and quantities of waste oil used. The applicator must also follow guidelines to prevent the entry of such oils into surface or groundwater, drinking water sources, or flowing waters. New regulations are expected to be promulgated in Vermont by the summer of 1988 which will prohibit the use of any waste oil as a dust suppressant (Reid, 1988).

Based on the above comments, it is apparent that individual states across the US vary with regard to their policy on the use of waste oils for road dust suppressant applications.

2.3 - Road Dust Suppressant Use in Canada

Table 2.2 provides a summary of the road dust suppressants known to be currently used in the provinces and territories of Canada. This table was developed primarily through personal discussions at the provincial level and through a literature review. In 1983 the types and volumes of dust suppressants used in southern Ontario were identified by Gillham et al (1985) and this information is summarized in Table 2.3.

TABLE 2.2

SUMMARY OF DUST SUPPRESSANT USE ON UNPAVED ROADS IN CANADA[1,2]

Province/Territory	Type of Dust Suppressant Used				
	Waste Oil	Calcium Chloride	Magnesium Chloride	Pulping Liquors	Salt Brine
Alberta	x[3]	x		x	
British Columbia	x	x	x	x	
Manitoba	x[3]	x		x	
New Brunswick	x[3,4]	x		x	
Newfoundland	x[4]	x			
Northwest Territories	x	x			
Nova Scotia	x[3,4]	x		x	
Ontario	x	x		x	x
Quebec[5]		x		x[6]	
Saskatchewan	x[3]	x		x	
Prince Edward Island	x	x			
Yukon	x	x			

[1] Excluding semi-permanent asphalt emulsions

[2] Based primarily on personal contact with provincial environmental and transportation agencies in February 1987.

[3] Provincial Dept. of Environment discourages use of oil as a dust suppressant.

[4] Not used by Dept. of Transportation

[5] Oil is banned for use as a dust suppressant in this province.

[6] Tembind is not considered a waste (Quebec legislation, Table 2.1) because it is reprocessed by acid neutralization and concentration.

TABLE 2.3

DUST SUPPRESSANTS APPLIED IN SOUTHERN ONTARIO (GILLHAM ET AL. 1985)

Southern Ontario Counties	Volume (Liters) Applied in 1983 Calcium Chloride (solution)	Used Oil	Brine	Pulping Liquor
Brant	1,424,413	66,376		
Bruce	4,167,166			
Dufferin	2,469,993			
Dundas-Stormont-Glengarry	4,309,608			
Durham	4,091,400	1,775,494		
Elgin	1,159,230		7,773,500	
Essex	3,198,868		1,141,046	
Frontenac	1,742,633	318,220		
Grey	4,803,606	72,000		
Haldimand-Norfold	2,273,000			
Haliburton	172,748	675,504		
Halton	578,826	365,528		
Hamilton-Wentworth	1,174,383	204,470		
Hastings	2,863,980	36,368		
Huron	5,727 960		477,330	
Kent	3,535 272		636,440	
Lambton	3,545,880		2,647,112	
Lanark	1,939,626			
Leeds and Grenville	3,126,132			
Lennox-Addington	925,868	1,710,800		
Middlesex	3,454,960		4,849,838	
Muskoka	780,396	1,291,230		
Niagara	2,803,366			
Northumberland	939,506	1,188,860		
Ottawa-Carlton	3,106,433			
Oxford	4,294,454		3,091,280	
Parry Sound		1,952,634		
Peel	2,779,121			
Perth	3,712,566			
Peterborough	2,551,821	878,542		
Prescott-Russell	1,800,216			
Prince Edward				1,450,000
Renfrew	1,682,020			
Simcoe	3,838,339	3,729,167		
Toronto	297,005			
Victoria	3,265,543			
Waterloo	2,159,350	1,027,300	727,360	
Wellington	4,962,716			
York	1,772,940			
TOTAL	98,564,856	15,292,493	21,344,066	1,450,000
% of Total	72	12	15	1

2.4 - Review of the Literature and Agency Discussions on Dust Suppressant Alternatives

2.4.1 - General

The Roads and Transportation Association of Canada recently sponsored a study on dust suppressants and developed a product selection chart based on traffic volumes, road subgrade type, surface material and climate. This information, plus a summary of performance limitations and preferred application rates and frequencies are provided in Appendix C.

A more detailed discussion of the three major dust suppressants identified as being of interest to this study (waste oils, calcium chloride, and lignosulfonates) is provided in the subsections below. The literature generally indicates that both calcium chloride and lignosulfonates are used extensively across Canada and are considered almost equal in terms of cost and control effectiveness. Variations in use are primarily due to proximity to sources and climatic conditions. The use of waste oils is generally on the wane, due to environmental concerns.

2.4.2 - Waste Oils

(a) Types

Waste oils include crankcase oils from automotive, railway, marine and farm equipment, and oil used in industry for cutting, machining and insulation.

(b) Inorganic and Organic Composition of Waste Oils

Gillham et al (1985) summarized much of the data available on the concentrations of various inorganic and organic

constituents of waste oils as listed in Appendixes D1 and D2. These appendixes include additional technical data collected from studies by Suprenant et al (1983), Love and Associates (1979) and Rudolph (1978).

(c) **Analytical Methodologies for PCBs in Waste Oils**

Recent work by OceanChem Laboratories indicates that PCB concentrations found in waste oils can vary depending on the analytical methodologies used and the time between sampling and analysis (Sirota, 1986). Appendix D3 shows the variation in total PCB levels found in samples containing mixtures of petroleum hydrocarbons and commercial PCB mixtures using a standard extraction/cleanup methodology and a modified cleanup method using fuming sulfuric acid. The modified method resulted in better accuracy. Appendix D4 illustrates the change in PCB concentrations over time of a surface sample of waste oil containing high levels of insoluble particulates.

(d) Environmental Effects

The main concern with the use of waste oils for road dust control is the impact of common constituents, e.g. heavy metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) on the surrounding environment. This is a legitimate concern given the levels of these contaminants found in waste oils as summarized in Appendixes D1 to D4.

One of the first attempts at defining the extent of contamination was carried out by Freestone (1972). Tests were carried out in the vicinity of two oiled roads in New Jersey to determine the extent of runoff to a nearby stream and the

extent of lead uptake in aquatic organisms, soils and plants. Two oil patches of "several square inches" were noted in shallow pools, on the banks of the small stream. However, no conclusions could be reached from results of the lead analysis on tissues of aquatic invertebrates. Soil and plant samples taken from a wheat field approximately 45 m from the road had slightly elevated lead concentrations (24.0 and 33.5 mg/kg, respectively) when compared with the expected background levels as established by Motto et al (1970).

The Freestone report has since been criticized by Bell (1976) who pointed out that the lead levels found in Freestone's soil and plant samples were well below average lead levels in rural Ontario.

Field investigations carried out by Love & Associates (1979) on Ontario road test sections in 1978 indicated that the predominant transfer route of waste oil from the roadbed to the roadside environment was by runoff following rainfall to the nearest drainage ditches and water courses, with a small amount accumulating in the shoulder soil.

Freestone (1972) estimates that 70 - 75% of the oil leaves the road by dust transport and runoff and that the remaining 25 - 30% is lost through volatilization, adhesion to vehicles, and biodegradation. Both Freestone (1972) and Suprenant et al (1983) conclude that penetration of contaminants downward through the soil is minimal.

In 1980 Suns et al reported elevated levels of PCBs in yellow perch tissue taken from 12 Muskoka lakes affected by the runoff from waste oil applications. The study found that 71% of the samples from lakes that received runoff from

oiled roads contained PCB concentrations in excess of IJC's wildlife protection guidelines.

A few years ago it was not uncommon to find widely varying quantities of PCBs in road oils. For example out of 22 samples of road oils tested by MOE in 1978, 13 samples had PCB concentrations of <5 ppm, 7 samples contained levels below 40 ppm, 1 sample contained 310 ppm and another contained 1135 ppm (MOE, 1978). However, Ontario's waste management regulations now require a certificate of approval to be obtained prior to the use of a dust suppressant and waste oils are routinely tested for PCB levels and other constituents prior to their use for this purpose.

Recently, the Ontario Ministry of the Environment sponsored studies to assess the potential for groundwater contamination by various dust suppressants (Gillham et al, 1985). It was concluded that because of dilution and geochemical retardation processes the inorganic constituents of waste oils will not likely have a negative effect on groundwater quality. However, the potential for groundwater contamination by organic constituents of waste oils remains very uncertain, since the fate of these materials in the environment is still not well understood.

Techman (1982a) advised that road safety may be reduced by road oiling based on 1977 MTC skid tests on roads in Haldimand Township. Oiled roads showed 25% less skid resistance when compared to untreated and calcium chloride treated roads but there was no information on the time after application when this occurred.

The US Environmental Protection Agency recently sponsored a study to evaluate the health risks associated with the use of waste oil as a dust suppressant. However, no definite

conclusions were reached and the degree of health risk is still being debated (Metzler, 1985).

(e) <u>Efficiency</u>

Love & Associates (1978) state that waste oil is superior to calcium chloride as a dust suppressant. The latter study was based on road sweeps of loose gravel on some Ontario roads in 1977. While the oiled sections of road compacted faster, they also broke up faster and to a greater degree, with potholes forming more readily in the oiled sections of road. Techman (1982) has also noted that roads where waste oils have been applied are prone to potholing in wet weather.

Dust control studies on roads in Quebec compared oil with liquid calcium chloride (Nolin, 1980). It was found that the oil treatment gave slightly longer protection on clay-based gravels and much longer protection on non-clay gravels.

Oil application rates for dust control are generally in the range of 1.1 - 1.7 L/m^2 to an upper limit of 2.7 L/m^2 (Techman, 1982; Love & Associates 1978), often applied in one application early in the season.

(f) <u>Cost</u>

A cost comparison for various dust suppressants was carried out by Gillham et al in 1985 (Table 2.4). This table indicates that used oil is the most expensive dust suppressant of the alternatives used in Ontario. The cost of $1858/km/yr for road dust control in Ontario using waste oil as shown in Table 2.4 compares with $1200/km/yr in British Columbia in 1985 (Wagar, 1987) and a range of $2500

TABLE 2.4

COMPARATIVE COST OF DUST SUPPRESSANT APPLICATIONS IN ONTARIO (1985 DOLLARS) (GILLHAM ET AL. 1985)

Suppressant	Region	Cost ($/L)	Mean Application Rate (L/km/yr)	Cost ($/km/yr)
Used Oil	S. Central	0.184	10 098	1,858
	Northern	0.198		
Calcium Chloride	S. Western	0.099	3 106	307
	S. Central	0.121	7 318	885
	S. Eastern	0.145	4 516	655
	Northern	0.150	4 008	601
Brine	S. Western	0.016	17 280	276
Sulphite Liquor	S. Eastern	0.003	16 948	50

to \$6000/km/yr estimated by Techman (1982) for northern and western Canada. However, details on the costing quoted in these references were insufficient to make realistic comparisons. Detailed knowledge of the many variables involved in developing a treatment cost is required, e.g., availability of product, transportation costs, road type, width and condition, surface preparation costs, number of dust control applications per year (varies with road material and traffic volumes), labor and machinery costs, climatic conditions, etc.

2.4.3 - Calcium Chloride

(a) Composition

Calcium chloride is deliquescent and hygroscopic, dissolving gradually and becoming liquid by attracting and absorbing moisture from the air.

Analysis of dust suppressant grade $CaCl_2$ flakes supplied by Allied Chemical was provided by Love & Associates (1978) as follows.

$CaCl_2$	77% (minimum)
Total alkali chlorides	1.8%
$Ca(OH)_2$	0.1%
Water	21.1% (variable)

Generally, the solid flake is 70-80% $CaCl_2$ while the solution contains 30 - 42% $CaCl_2$ (Techman, 1982).

(b) Environmental Effects

While it has been stated that calcium chloride may adversely affect water supplies, plants and aquatic species (Techman

1982), no documentation was found to indicate these effects have occurred from the use of calcium chloride as a road dust suppressant. In B.C. the policy of the Ministry of Transportation and Highways is not to use chlorides where there are drinking water wells within 10 m of the roadway (Wagar, 1987).

Other problems with calcium chloride have been identified by Techman (1982) as follows:

- poor quality soils take longer to recover from wetting

- complaints from taxpayers about excess rusting of vehicles

- fresh calcium chloride causes drying and cracking of leather (workers should wear rubber boots)

- a surface crust created by $CaCl_2$ may be slippery in wet weather.

In New Brunswick, calcium chloride is discouraged due to complaints of well contamination from road salting, and local government environmental officials fear that the use of $CaCl_2$ as a dust control agent will only add to the problem (New Brunswick Department of Municipal Affairs and the Environment, 1987). Midwest Research Institute (1981) advises that a 30% $CaCl_2$ can be injurious on contact to eyes or skin.

Despite the above drawbacks, recent inquiries by Acres to provincial environmental agencies across Canada indicate that calcium chloride is still the preferred road dust suppressant in most provinces.

(c) <u>Efficiency</u>

Field investigations by the Quebec Ministry of Transport compared a mixture of calcium and sodium chloride flakes (2.26 metric tonnes/km) with calcium chloride liquid (0.9 L/m^2) and flake (2.26 metric tonnes/km). They found that for gravels containing silt (11.7%) and clay (3.7%) subgrades, a 50-50 flake mixture of NaCl and $CaCl_2$ is slightly less effective than $CaCl_2$ in liquid or flaked form. For gravels with little silt (4.8%) and clay (2.5%) there was no difference in performance between treatment with a 50-50 flake mixture of NaCl/$CaCl_2$ and liquid calcium chloride (Langlois and Dallaire, 1979).

While calcium chloride is generally considered an effective dust suppressant, it is less effective than lignosulfonates when very dry (Techman, 1982; Boyd, 1983). It is most effective in areas where relative humidities exceed 30% (Techman, 1982). A comparison between the performance of calcium chloride and calcium-based lignosulfonates is provided for road test sections in Manitoba.

(d) <u>Cost</u>

Costs obtained by Gillham et al (1985) for calcium chloride ranged from 10 - 15c/L and $300 - 600/km/yr, with the lower costs applying to southern Ontario and the higher to northern Ontario. This is considerably less costly than the 18 - 20c/L cost for used oil in Ontario but much more expensive than 2c/L for brine and 0.3 c/L for sulphite liquor.

In Quebec it was found that calcium chloride in flake form was 18% less expensive than similar protection in liquid form, although fewer trucks are required for the liquid application. Also, a 50-50 NaCl/$CaCl_2$ mixture was found to be 39% less costly than calcium chloride flakes (Nolin, 1980).

At four sites in Manitoba, Boyd (1983) found costs for the supply and application of $CaCl_2$ and lignosulfonates to be essentially the same. There were no significant differences in maintenance requirements, except at one site which required additional applications of a lignosulfonate.

2.4.4 - Lignosulfonates

(a) Composition and Types

Lignosulfonates are organic, non-bituminous binders that are byproducts of the sulfite pulping process.

The organic constituents of sulfite liquor and some commercial lignosulfonates are presented in Appendix F. There are five types of lignosulfonate compounds which may be used as dust suppressants (Techman, 1982)

- crude lignosulfonate (untreated spent sulfite liquor)
- calcium (Ca)-based
- sodium (Na)-based
- magnesium (Mg)-based
- ammonium (NH_3)-based

(b) Environmental Effects

Norman (1984) conducted an environmental assessment of lignosulfonates used as dust suppressants and much of the information that follows has been summarized from that report.

Lignosulfonates and spent sulfite liquor reduce dissolved oxygen as evidenced by Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). Color and the quantity of suspended solids in water are also increased. Since color

reduces light penetration to the water, this can in turn, reduce the photosynthetic action of aquatic flora. However, the most serious concern is with fish toxicity. Background data in support of California water quality criteria in 1963 provided the following toxicity details for spent sulfite liquor (see Appendix F)

- 100 ppm of the non-aqueous portion of spent sulfite liquor is lethal to trout in a few days

- 200 - 500 ppm killed warm water fish in 10 - 20 days

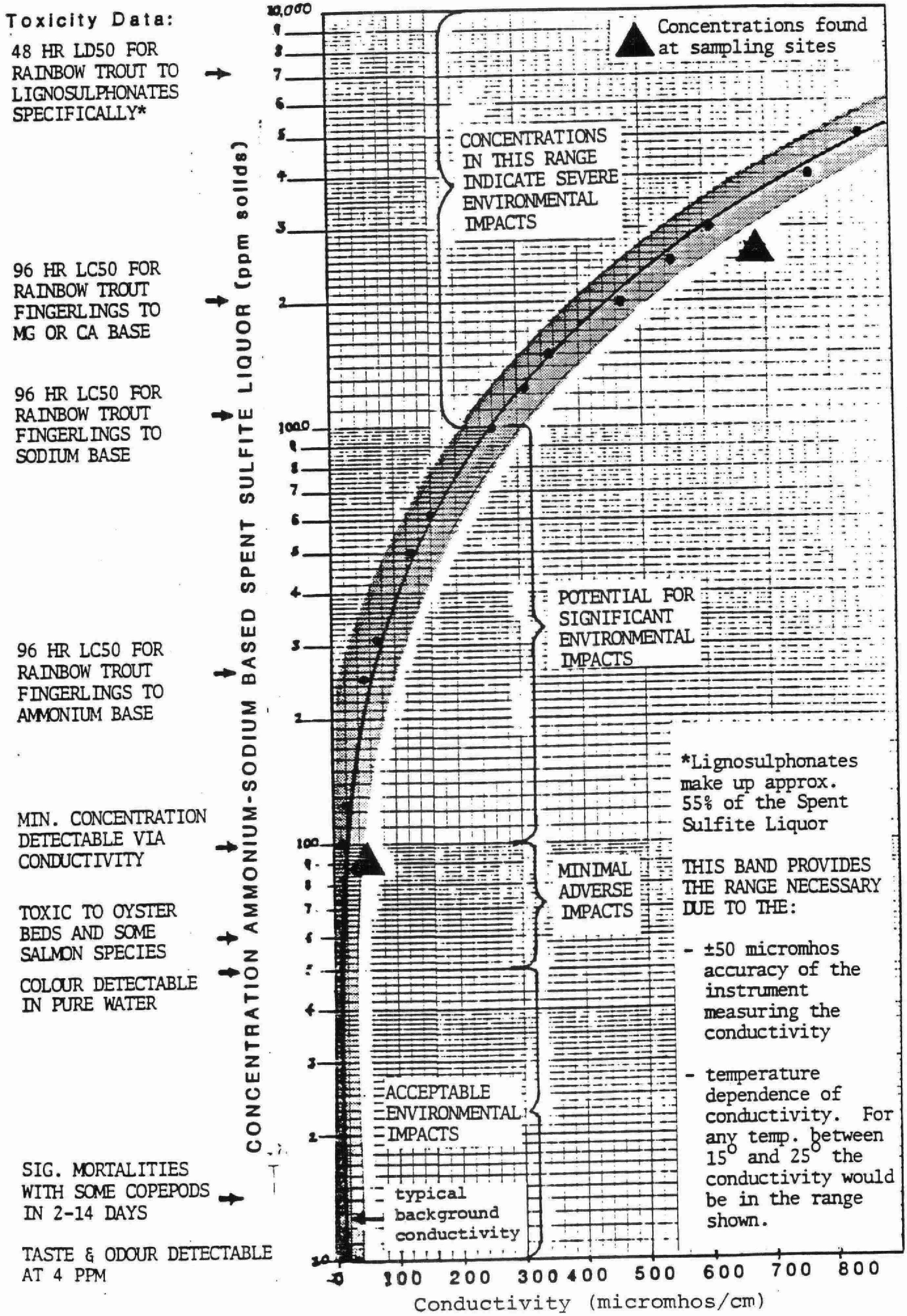
- some copepods could not tolerate spent sulfite liquor, with significant mortalities being reported at 5 - 15.7 ppm solids in 2 - 14 days.

Based on the California toxicity data collected by Norman and using an ammonium-sodium lignosulfonate sample provided by Temfibre, a graph was developed (Figure 2.1) showing the relationship between conductivity, concentration (ppm) and environmental effects.

Research by Wong (1981) indicates that the toxicity of spent sulfite liquor to fish is variable and is dependent on the pulp yield, with a higher pulp yield resulting in a lower toxicity. Wong observed that toxicity decreased sharply in the pulp yield range of 40 - 55%, and hypothesized that the degree of toxicity was related to the amount of extractives (e.g., resin and fatty acids) present in the wood and the concentrations of lignin degradation products.

Norman (1984) notes that Temfibre Ltd. operates a low yield acid sulfite mill. Their product (Tembind 25) which is 25% solids, was tested by MOE on a road in 1985 and the results

Figure 2.1 Concentration vs Conductivity for an Ammonium-sodium Based Spent Sulfite Liquor (Norman, 1984)



are presented in Appendix F. No environmental effects were measurable, even after a heavy rainfall which could have produced significant runoff to a waterway which was within 1 m of either side of the roadway. This is the only identified lignosulfonate road test to date performed specifically to determine environmental effects. Tembind is reprocessed by acid neutralization and concentrated by evaporation. The manufacturer cited US Food and Dug Administration Federal Regulations which allow the use of lignosulfonates as a binder (up to 4%) in the production of animal feed (Majors, 1988).

Research has been done on the relationship between other lignosulfonates and fish toxicity. The Environmental Protection Agency (1980) found a commercial lignosulfonate road stabilizer to be moderately toxic to rainbow trout. Roald (1977a) found no clear relationship between lignosulfonate concentrations and growth retardation in rainbow trout but in another study involving rainbow trout (1977b), he indicated that lignosulfonates may be an important factor in effluent toxicity of spent sulfite liquor. This was based on a 48 hour LC_{50} for rainbow trout at a concentration of 7300 ppm lignosulfonates and a 275 hour LC_{50} at a concentration of 2500 ppm. In view of the research findings to date, it would appear prudent to recommend avoiding application of lignosulfonates as a dust suppressant in the vicinity of spawning sites and cold water streams supporting trout.

Under appropriate temperature and moisture conditions, spent ammonia-based sulfite liquor can provide fertilizer benefits. These include nitrogen, sulphur, sugar consumption by micro-organisms as a carbon source, and lignin's contribution to the humus component of the soil (Bollen, 1955). However, since lignosulfonates do not penetrate through soil to any extent (Norman, 1984), their environmental benefits to soils would be negligible.

Based on the limited literature available, lignosulfonates appear to produce little systemic toxicity to humans or animals (Singer et al, 1982).

(c) Efficiency

Field trials on lignosulfonates (Tembind 35) at 21 sites around Ontario were carried out in 1984 by the Ontario Ministry of Transportation and Communications as described in Appendix E. McDougall (1986) summarized the results of these trials as follows:

- lignosulfonates were most effective on sedimentary, high fines crushed rock and less effective on igneous, medium to low fines, crushed gravels

- lignosulfonates were less effective than road oil and nearly as effective as calcium chloride

- where performance failures occurred, they were due to loss of dust palliative following rains and application on unconsolidated roads

- lignosulfonates perform best under arid conditions.

Boyd (1983) also found that calcium and sodium-based lignosulfonates performed well on test roads in Manitoba under dry to normal weather conditions and on roads with clay subgrades. Where lignosulfonates did not perform well, there were above average rainfalls and sandy subgrades.

Techman (1982b) reports that an ammonium-based lignosulfonate was found to be very effective in Port Alice, B.C., regardless of very high rainfall (2920 mm annual average). They also advise that lignosulfonate effectiveness increased with higher dissolved solids content (Techman, 1982a).

Studies by Sontowski and Vliet (1977) indicate that calcium lignosulfonate produced 72% less dust than sodium lignosulfonate and 56% less than ammonium lignosulfonate, presumably due to the deliquescent properties of the calcium. However, the BC Ministry of Transportation and Highways considers that calcium and sodium lignosulfonate are equally effective in most arid areas of BC (Wagar, 1987).

General performance criteria for lignosulfonate dust suppressants have recently been developed for the Roads and Transportation Association of Canada and this information is summarized in Appendix C.

(d) <u>Cost</u>

Aquin et al (1986) compared the cost and control effectiveness of Tembind 35 lignosulfonate with waste oil and calcium chloride at various test sites around Ontario. The rating system is described below and the results are shown in Table 2.5.

A maximum of 10 was assigned for no dust and no potholes. The cost factor was given a maximum rating of 20 for the least expensive as cost is a major consideration when choosing a dust palliative. The percent rating was obtained by adding the three ratings, dividing by 40 and multiplying by 100. Aquin et al concluded that Tembind 35 is relatively effective when compared with calcium chloride and waste oil. However, they caution that other factors should also be considered when assessing cost and control effectiveness e.g., cost of treatment per square meter, savings from reduced grading, period of time dust is effectively suppressed, the reduction in granular materials losses and environmental constraints.

TABLE 2.5

COST AND CONTROL EFFICIENCIES OF
TEMBINE 35 COMPARED WITH WASTE OIL
AND CALCIUM CHLORIDE (AQUIN ET AL. 1986)

	Rating (1)			
	Maximum	Tembind 35	Waste Oil	Calcium Chloride
Dust Control	10	8.5	10.0	8.3
Resistance to Potholing	10	8.1	9.2	8.3
Cost (Typical, $/km)	20	16.6 (1312)	17.0 (1285)	20.0 (1090)
Total: (2)	40	33.2	36.2	36.6
Number of Sites (3)	-	16	4	2
Rating, % (4)	100	83	91	92

Notes

(1) Rating: the higher the number is the better rating.
(2) Total: the sum of the ratings.
(3) Number of test sections where the material was used.
(4) Rating % = percent of total available points (40).

2.4.5 - Other Products

A number of other products have been tried for road dust suppression and these are described in Table 2.6. Generally they are considered inferior to waste oils, calcium chloride and lignosulfonates in terms of effectiveness and/or cost except for magnesium chloride. The latter is used extensively in B.C., particularly in arid areas and is available at a cost comparable to calcium chloride.

Other waste products which may have potential for dust suppression are as follows (Techman, 1982a)

- fly ash
- hydrogenated tallow
- sulphur
- rubber latex
- calcium or magnesium carbonate from water softening operations.

However, none of the above products is known to have been tested for dust suppression effectiveness and some products may have adverse environmental implications.

2.5 - Summary

Waste oils, calcium chloride and lignosulfonates are all considered to be effective road dust suppressants. Love and Associates (1978), Nolin (1980), Techman (1982b) and Aquin et al (1986) found waste oil to be superior in performance to calcium chloride, although both Love & Associates and Techman (1982a) note that oiled sections of roads are prone to potholing in wet weather. UMA Engineering (1987), however, indicated that petroleum products do not perform quite as well as calcium chloride or lignosulfonates. Therefore, while all of these dust suppressants are considered to perform reasonably well, there is

TABLE 2.6

OTHER PRODUCTS USED FOR DUST SUPPRESSION[1]

Product	Effectiveness	Cost	Environmental Considerations
Petroleum-based resins (e.g. Coherex)	Varies from bad to good; supplier indicates suitable alternative to $CaCl_2$ in very dry conditions; may coagulate if improperly stored.	0.33 - 0.66/L FOB Job Site (1982)	Concentrated emulsion of petroleum oils and resins may cause adverse impacts. Apparently non-injurious to plant growth and causes no oxygen decrease in waterways.
Salt brines	Low content brines (i.e. 7-15%) are generally not recommended for heavy traffic but good for low volume traffic.	0.014/L (1981) from supplier; If it contains >7% calcium chloride, it may be less expensive than commercial $CaCl_2$	Mildly toxic to some plants such as fruit trees; may cause corrosion of vehicles.
Sodium chloride (rock salt)	Not recommended because it requires high relative humidity (70-80%) to be effective; used successfully with $CaCl_2$ but not as effective as straight $CaCl_2$.	Not considered best dollar value for taxpayers	Mildly toxic to some plants such as fruit trees; may cause corrosion of vehicles.
Magnesium chloride	Used successfully in B.C. especially in arid areas	Similar to $CaCl_2$	Mildly toxic to some plants such as fruit trees; may cause corrosion of vehicles.
Water and wetting agents (e.g. Alchem)	Requires frequent applications (i.e. daily or every 2 - 3 days); not recommended for long-term dust suppression.	Not available	Aliphatic hydrocarbons and surfactants in wetting agents may be potentially toxic
Whey from dairies	Tests in Dauphin, Manitoba resulted in slippage of vehicles immediately after application.	Not available	Environmental impacts unknown.

[1]This table was developed primarily from data collected by Techman (1982 a, b) except where otherwise noted.

no clear consensus on one product outperforming the other. In many cases, absence of details on variables such as traffic volumes, sub-grade types (clay, silt, etc) surface material, climate, etc, make it extremely difficult to compare various road tests undertaken to date on these three dust suppressants. Nevertheless, lignosulfonates are considered by most investigators (e.g., Techman, 1982; Boyd, 1983; McDougal, 1986; and UMA Engineering, 1987) to be superior in dry climates and calcium chlorides to be most effective where relative humidities exceed 30%. UMA Engineering (1987) indicates that petroleum based products are generally effective under any climatic conditions except rain.

With regard to environmental impacts, there is still considerable concern regarding the use of waste oils, primarily due to the unknown environmental effects of their organic constituents on the roadside environment and local streams. There is also concern that lignosulfonates could adversely affect fish populations, particularly where runoff occurs to trout streams. The main concern with calcium chloride is with its 'salting' effects on water supplies and possibly plants and aquatic biota. However, no documentation was found in the literature or through discussions with transportation or environmental agencies that indicated adverse environmental impacts as a result of calcium chloride or lignosulfonate use as a road dust suppressant. It must also be recognized, though, that very little research has been carried out in this area to date.

Costs quoted in the literature varied considerably even within the same province (see Tables 2.4 and 2.5), and it is difficult to draw any conclusions without a detailed analysis of the basis for costing. Undoubtedly, costs will vary depending on geographic location, product availability, willingness of local supplier to be competitive with other products sold in the area, application rate, number of applications, etc.

3 - SITE SELECTION

3 - SITE SELECTION

The sites for the field studies were selected with the assistance of the project officer from MOE. Following the review of suppressant usage, Acres was requested to identify sites for six suppressants

Calcium chloride
Lignosulfonate
Waste "industrial" oils
Waste "crankcase" oils
Tembind (commercial lignosulfonate based binder)
Salt brine

The criteria for the site selection included duration of continuous treatment with the designated suppressant, proximity, and "representativeness". At a more detailed level, in the selection of the specific sampling sites was done in consideration of relative uniformity of the test section, lack of other nearby dust sources, cooperation of local residents (if any) and general accessibility.

Candidate sites were first identified during the review of background material. The road authorities responsible for the suppressants of interest were telephoned to find out if sections of road were available to meet the selection criteria. This proved to be a time consuming task. Most sites were ruled out because of the use of different substances or suppliers within the time of interest, or because the information was unavailable or inaccurate. Finally, six local areas were identified, and specific sites were chosen in the first of four site visits. The sites, described in detail in Section 5, were:

1 - Niagara-On-The-Lake (calcium chloride)
2 - Hallowell (lignosulfonate)
3 - Milton (waste "industrial" oils)
4 - Armour (waste "crankcase" oils)

5 - Coleman (Tembind)

6 - Blandford-Blenheim (salt brine).

In the review of previous work, it was found that dustfall jars deployed in other studies had been subjected to persistent vandalism. In this study, the jars were placed on stands in the open or near fence lines or other supports (not large obstructions, which were avoided), that would make them less obvious. None of the samplers was vandalized during the study, although a few were disturbed accidentally. The result of this is that the specific locations of samplers at each site reflected the local obstructions and opportunities for concealing the samples.

4 - FIELD PROGRAM

4 - FIELD PROGRAM

4.1 - Dustfall Sampling

Dustfall is a low cost but coarse index of the impact of local fugitive dust sources to the atmosphere monitored over a nominal 30-day period. It is measured by exposing an open top collector jar to the air for a month. The material collected in the jar is rinsed out, filtered, and weighed after organic debris such as leaves and insects, have been removed. The procedure used in this study generally follows the "Standard Method for Collection and Analysis of Dustfall" (ASTM D1739-70) as adopted by MOE, but with several exceptions. The dustfall jars used by MOE have dry polyethylene liners. Those used in this study had no liners, and contained an initial amount of copper sulfate solution as an inhibitor to algae. Dustfall methods also differ in the type of collector used. The ASTM collector is larger than that used by MOE. A previous consultant to MOE had found wide-mouth "mason jars" to be a cost-effective and efficient alternative. It was agreed with the scientific officer that they would be used in this study.

The terms of reference specified four dustfall jars at each site--two on either side of the road--but following review it was considered desirable to use more, the actual number being determined by the site layout. The maximum number at any site was eight in the following configuration: three were placed 1.5 m high on each side of the road at 8 m, 16 m and 32 m from the centerline; one was placed on each side at approximately 2.2 m height on telephone or hydro poles, typically 8 m from the road centerline. The height of 2.2 m was reachable by the field technician and approximated the 2.4 m (8 ft) height suggested by ASTM. Although it was recognized that the vehicle-generated dust plume would be closer to a height of 1.5 m (hence that choice), the higher elevation on utility poles seemed less susceptible to tampering and jars at that height were used in addition to the 1.5 m high jars where possible. The collectors at 1.5 m were mounted in brackets either on

fence ports or on independent steel rods driven into the ground. Plate 4.1 illustrates the collectors, brackets and stands.

4.2 - Rain Gauge

Although not specified in the terms of reference, it was recognized that the rainfall should be measured at the site because of the potentially for a large variation between the rainfall at the site and the nearest Atmospheric Environment Service (AES) station. Simple rainfall gauges were made for installation at each site. Precautions were necessary to reduce the large error that could be caused by evaporation during the unattended month of operation. Each rain gauge was made using the cap ring and jar of the wide-mouth mason jar. A plastic funnel was cut to fit exactly beneath the screw ring, thus providing a wind baffle. About 3 mm of mineral oil was poured into the rain gauge during installation to further reduce evaporation.

4.3 - Surface Sampling

Samples were obtained from the road, the ditches, and adjacent land for chemical analysis. Because of the distribution of wind directions in Southern Ontario, the east side of a north-south road is (more often) downwind and is referred to as such in this report. Similarly, the north side of an east-west road is more often downwind, although over short time periods the prevailing wind directions may not be dominant. The sample locations using this reference frame based on the prevailing winds are:

1 - Road center, 0 - 10 cm
2 - Road center, 10 - 20 cm
3 - Downwind, tire track, 0 - 10 cm
4 - Downwind, tire track, 10 - 20 cm
5 - Downwind, extreme edge, 0 - 10 cm
6 - Downwind, extreme edge, 10 - 20 cm

(a) DUSTFALL JAR AND RAIN GAUGE

(b) MOBILE COLLECTOR MOUNTED BEHIND VEHICLE

PLATE 4.1

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
SAMPLING INSTRUMENTS

ACRES

7 - Upwind, ditch, soil
8 - Upwind, ditch, vegetation
9 - Downwind ditch, soil
10 - Downwind ditch, soil (dup)
11 - Downwind ditch, vegetation
12 - Downwind ditch, vegetation (dup)
13 - Upwind background soil (50 m from road)
14 - Downwind background soil (50 m from road)
15 - Upwind vegetation identification
16 - Downwind vegetation identification.

The last two samples were used for the site descriptions provided in a subsequent section. The other samples were subjected to chemical analysis as described in the next section.

4.4 - Analytical Procedures

4.4.1 - Dust Suppressants

(a) Metals

The metals in the dust suppressants were measured by two methods. The samples were subjected to inductively coupled plasma analysis (ICP). A second set of subsamples was analyzed using atomic absorption techniques. The dust suppressants were subjected to a strong acid digestion using a 2:1 mixture of nitric and hydrochloric acid and the digestate analyzed by atomic absorption spectrophotometry for the various metals. A sample weight of approximately 2 g was digested (except for the salt solutions where 50 mL aliquots were used) the volume brought up to 50 mL, filtered and analyzed by flame atomic absorption. Selenium was analyzed by graphite furnace atomic absorption.

The 35% solutions of $CaCl_2$ were diluted and tested for total mercury using the Environment Canada method for the determination of mercury in saline water by automated U.V. digestion cold vapor atomic absorption.

(b) Polychlorinated Biphenyls (PCB)

PCBs were analyzed in oils by MOE Method C. One gram of oil was weighed and dissolved in 50 mL of methylene chloride. The solution was passed through a florisil column and eluted with 1% v/v benzene in hexane and then concentrated using a rotary evaporator. A Varian 3300 gas chromatograph equipped with capillary column and electron capture detection (ECD) was used for the analysis. In some instances where further clean-up was required, a mixture of fuming sulfuric acid and concentrated sulfuric acid was used.

(c) Chlorinated Solvents

Trichloroethylene and tetrachloroethane were estimated in the oils by the following quick scan. One gram of oil was dissolved in 10 mL of hexane. One uL of this solution was then injected into the gas chromatograph.

4.4.2 - Soil, Road and Ditch Samples

(a) Metals

These samples were analyzed for nonresidual metals using the Environment Canada 0.5 N Hydrochloric Acid Extraction method. This involved weighing out a 5-g <80-mesh portion of homogenized sample, adding 50 mL of 0.5 N HCl and shaking it overnight. The extract was then filtered through a 0.45 micron cellulose acetate filter and analyzed by flame atomic absorption (furnace atomic absorption for Se).

(b) Chloride

Chloride was tested on the filtered extract obtained from a distilled water leach of the samples. This preparation requires taking a 5-g <80-mesh portion of sample and shaking it overnight in 50 mL of distilled water. The extract is then filtered and run by autoanalyzer using the Environment Canada Automated Thiocyanate method.

(c) Polychlorinated Biphenyls (PCB)

Ten grams of soil was blended with acetonitrile and the extract was exchanged into petroleum spirits, passed through sodium sulfate and condensed to 2 mL by a rotary evaporator. The extract was then cleaned on a florisil column, concentrated and analyzed by a gas chromatograph equipped with ECD and capillary column.

4.4.3 - Vegetation

(a) Metals

All vegetation samples were washed, shredded, homogenized and subsampled for metals, PCBs and chloride analysis. A strong acid digestion similar to the one described for the dust suppressants was used to extract the metals from the vegetation. The digestate was then analyzed by atomic absorption.

(b) Chloride

The prepared vegetation samples requiring chloride analysis were extracted and analyzed using the method outlined in Section 4.2.2.

(c) Polychlorinated Biphenyls (PCB)

The prepared vegetation samples requiring PCB analysis were extracted and analyzed using the method outlined in Section 4.4.2(c).

4.5 - Vehicular Dust Generation Experiments

In each of four visits to the site, two runs were conducted to further define the source strength of the road section and to remove some of the variability due to uncontrolled factors in the dustfall program.

In each experiment mobile and fixed samplers were operated while a vehicle was driven along the test section at a fixed speed of 70 km/h. The stationary equipment included two standard high volume air samplers ("hi-vols"), one on either side of the road, approximately 3 m from the edge of the road. These were operated for approximately four hours while the vehicle runs were performed. During these runs, a vehicle was driven along the test section of road at 70 km/h while three additional collectors were operated. Two of these were mounted on the vehicle and the third was mounted on the downwind hi-vol. These devices were personal sampling pumps drawing air at 3 Lpm through membrane filter cassettes. The two cassettes on the vehicle were located 2 m behind the vehicle at heights of 1 and 3 m as specified by the Scientific Officer for the MOE. During preliminary testing of the apparatus and analytical method, it was found that exposures of 20 min were suitable for the subsequent determinations of filter loadings. Two runs were performed during each sampling visit. The sampling apparatus is shown in Plate 4.1 A subjective rating of dust control was also made during the runs.

After the experiments, the hi-vol filters were returned to Acres' laboratory for standard gravimetric loading determination. A road surface sample was also obtained for determination of moisture content.

The membrane filters were taken to Brock University where the total mass and distribution of the mass in three size ranges was determined by computer enhanced image microscopy (Quantimet 720). Concentrations of the particles in air were calculated from the exposure time, flow rate and filter loadings.

5 - SITE DESCRIPTIONS

5 - SITE DESCRIPTIONS

5.1 - Niagara-on-the-Lake (Calcium Chloride)

The Niagara-on-the-Lake (NOTL) site, shown in Figure 5.1 and Plates 5.1(a) and (b), is part of Concession 6 north of Niagara Falls and just south of Line 8. The airport and weather office are located approximately 4 km northwest of the site. The test section is straight and flat and is fairly heavily travelled. Calcium chloride has been applied for perhaps 10 years or more except for a single test application of a proprietary product in 1984. Grape vines are cultivated in the surrounding farmlands.

The roadside ditches are thickly vegetated with the composition shown in Table 5.1.

5.2 - Hallowell (Lignosulfonate)

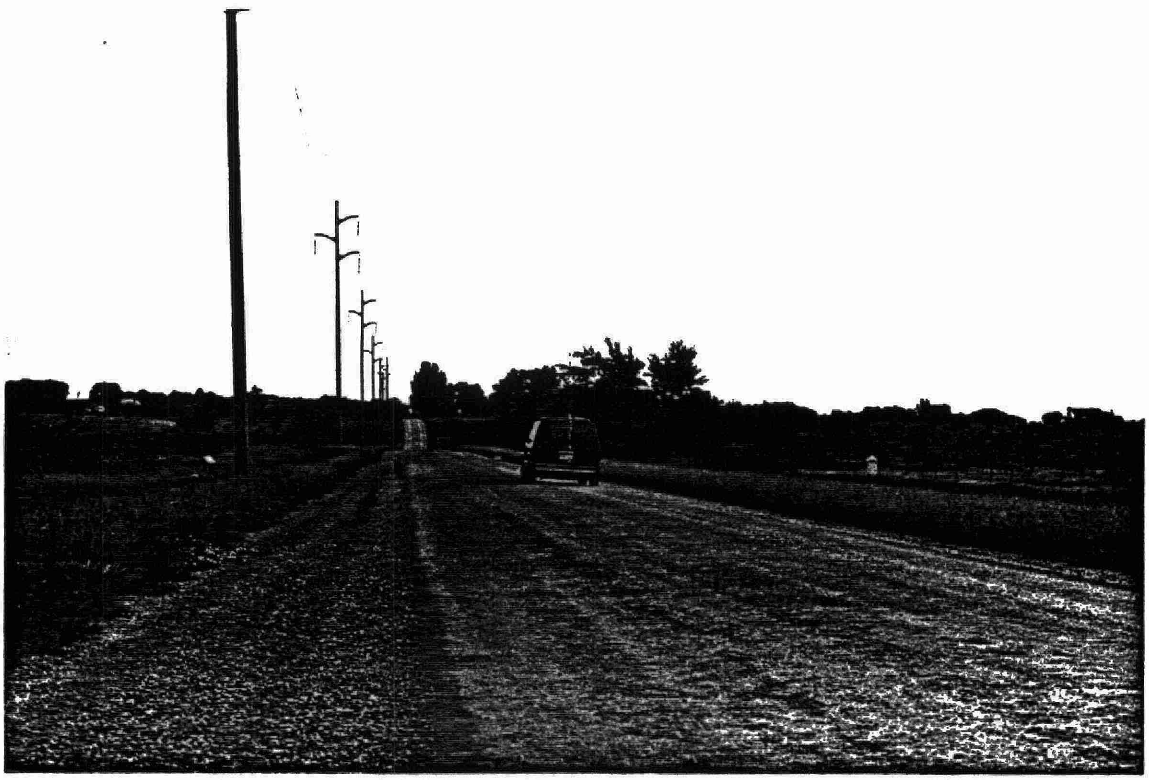
The test section for lignosulfonate, shown in Figure 5.2 and Plates 5.2(a) and (b) is under the jurisdiction of Hallowell Township, and is located 7 km southwest of Picton. Township vehicles obtain the spent pulping liquor from the Domtar plant in Trenton where the material is provided free of charge to all road authorities wishing to use it. It is applied as often as three times weekly. The freshly applied solution has a distinctive odor similar to sawdust and molasses. Although not offensive, the odor is persistent but does diminish considerably as the substance dries. While wet, the lignosulfonate is sprayed up by tires of passing vehicles. Coating them with a brown sticky film. This is removed easily with cold water. As the lignosulfonate dries it gives the impression of congealing and the road looks similar to an oiled surface. The main disadvantage of lignosulfonate is that it is readily water soluble, leading to unsightly runoff during rain and the need for frequent application.

Fig. 5.1

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
NIAGARA ON THE LAKE DUST SUPPRESSANT TEST SITE

ACRES

(a) SITE, FACING NORTH



(b) SITE, FACING SOUTH

PLATE 5.1

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
NIAGARA ON THE LAKE SITE

ACRES

TABLE 5.1

ROADSIDE VEGETATION AT DUST SUPPRESSANT TEST SITES

	NOTL (%)	Hallowell (%)	Milton (%)	Armour (%)	Coleman (%)	Blandford-Blenheim (%)
Family Graminae (Grass)						
Bromus sp.	>35	75	>99	95	50	
Panicum sp.	30	25				
Sparobolus sp.	30					
Phragmites sp.						100
Nardus sp.				5		
Family Salicaceae (Willow)						
Salix sp.				<1		
Family Equisetaceae (Horsetail)						
Equisetum sp.					50	
Family Chicoraceae (Chicory)						
Leontodon sp.			<1			
Family Rosaceae (Rose)						
Potentilla sp.		<1				
Family Plantaganaceae						
Plantago sp.	<1					
Cirsium sp.	5					

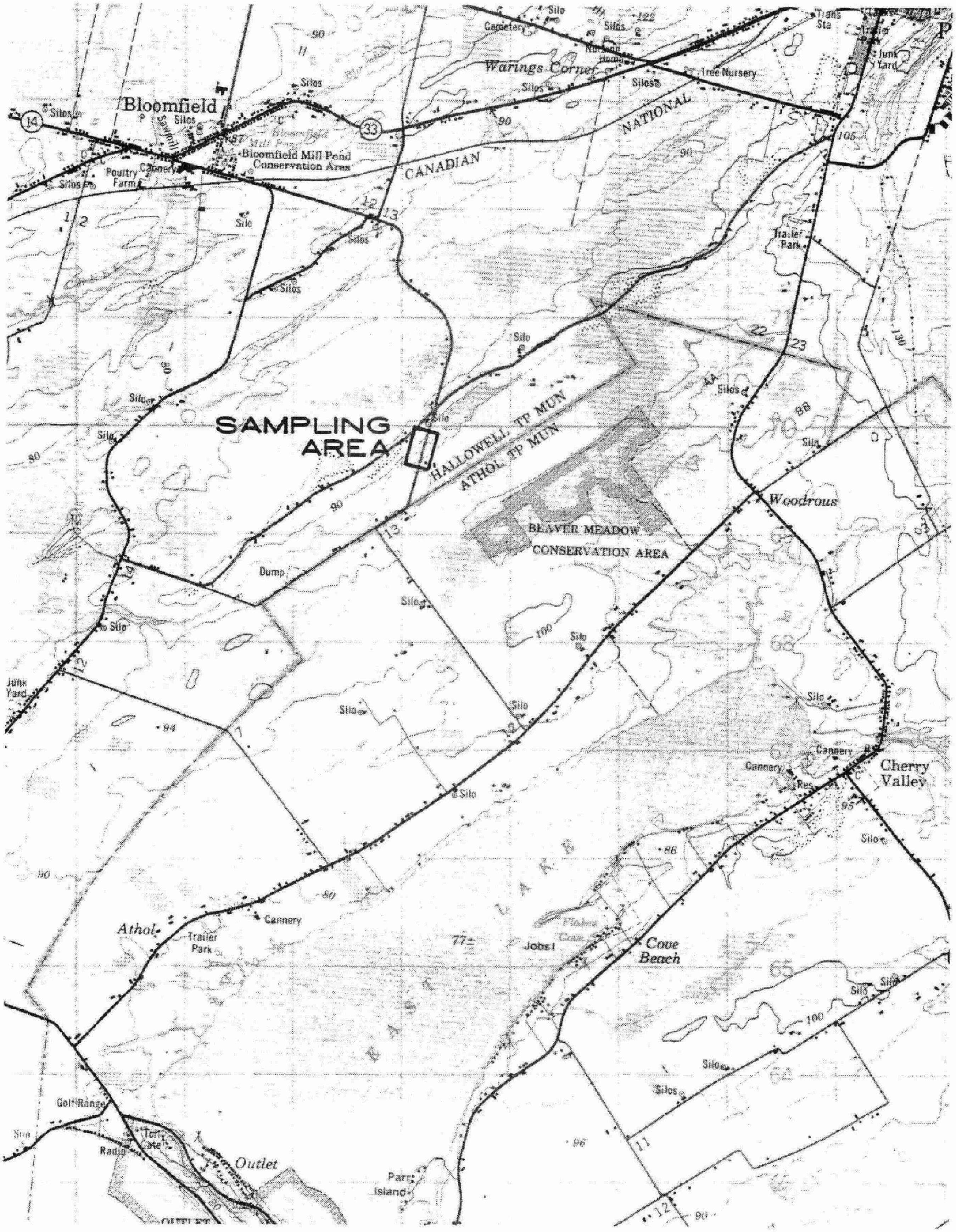
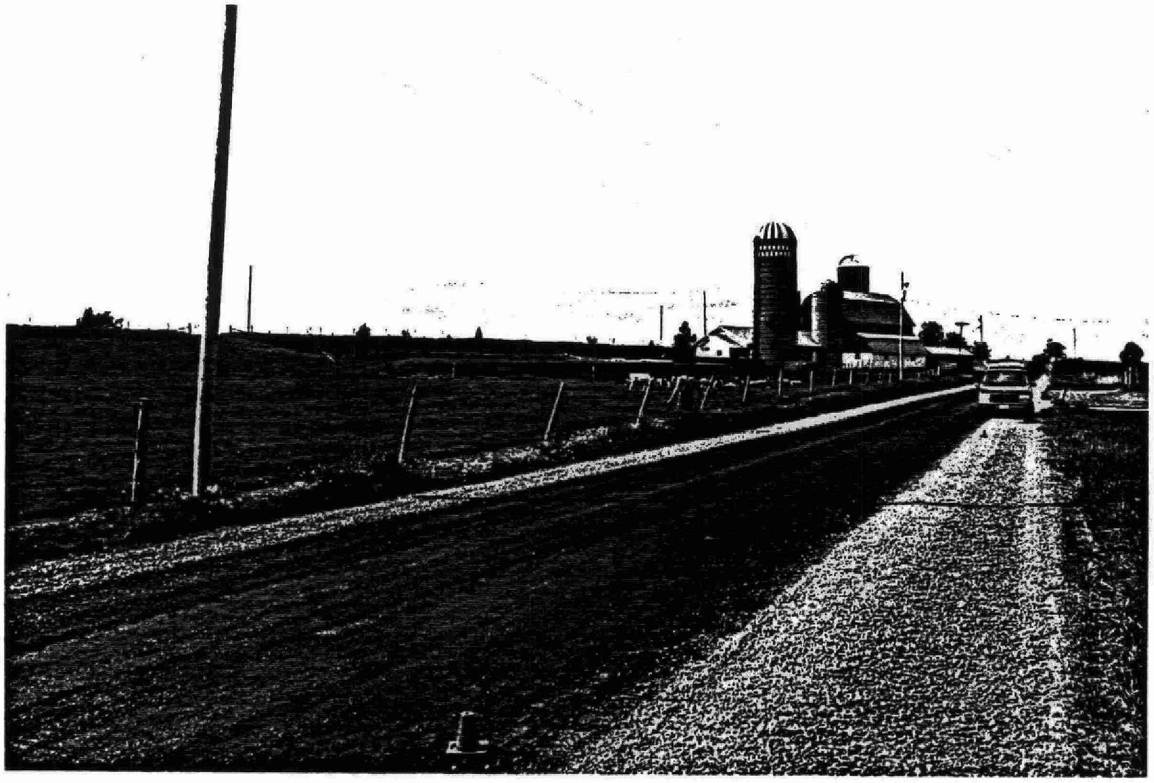


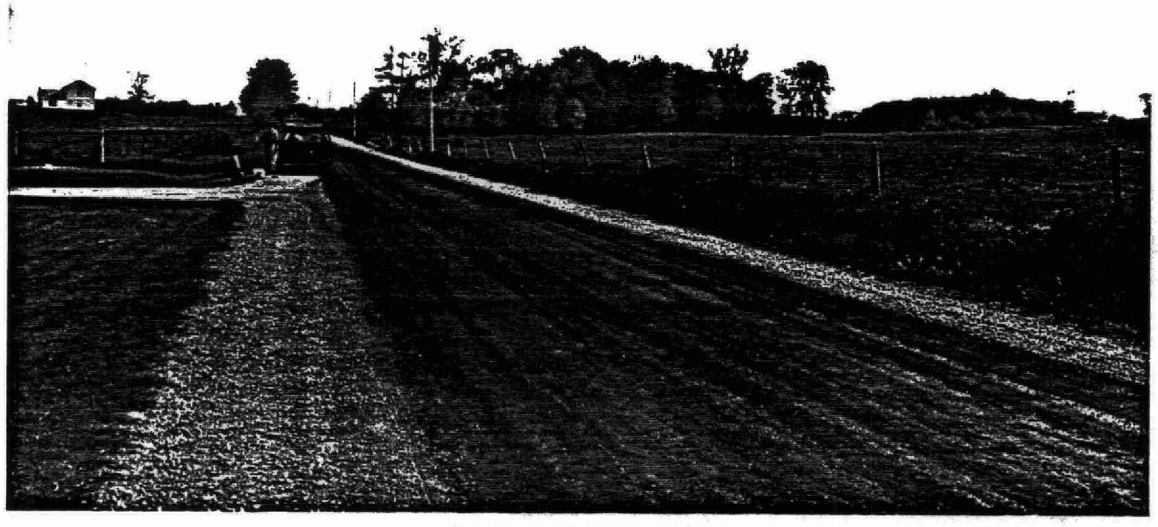
Fig. 5.2

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
HALLOWELL TOWNSHIP DUST SUPPRESSANT TEST SITE

ACRES



(a) SITE, FACING NORTH



(b) SITE, FACING SOUTH

PLATE 5.2

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
HALLOWELL SITE

ACRES

The test road section provides the main access to the township landfill in addition to regular traffic. On the west side of the road is the pasture of a dairy farm. A small creek runs through the pasture and through a culvert under the road just north of the test section. On the east side there is a fallow field surrounding a mobile home on a lot of about 60 m by 60 m. The dustfall jars in the east side were mounted on the fenceposts of this lot. On the west side, fenceposts were used for the near collectors, others were placed in the pasture, out of the path of the dairy herd where possible. Alternative sites along the road had either poorer exposures or were adjacent to ploughed fields.

Species of vegetation in the ditches are listed in Table 5.1.

5.3 - Milton (Industrial Waste Oil)

The distinction between 'industrial' and 'crankcase' mixed oils was made by MOE on the indirect basis of collection area. It was assumed that major waste oil recyclers in the industrial areas of southern Ontario would get a more diverse mix of oils from industrial sources, whereas a recycler in rural central Ontario whose collections were mainly from service stations would have predominantly a used crankcase oil mix.

The waste oil used by the Town of Milton for dust suppression is supplied by a large collector/recycling operation in southern Ontario. Side Road No 2 was selected for the test section, specifically the part north of Highway 401 near Mohawk Raceway. There is a heavily used campground at the end of the road section which is also used by many of the commercial vehicles, large trailers and other private race track traffic. Figure 5.3 and Plates 5.3(a) and (b) show the location.

Oil was applied in mid-May just before the initial sampling visit. This was to be the only application of the year. The odor of used oil

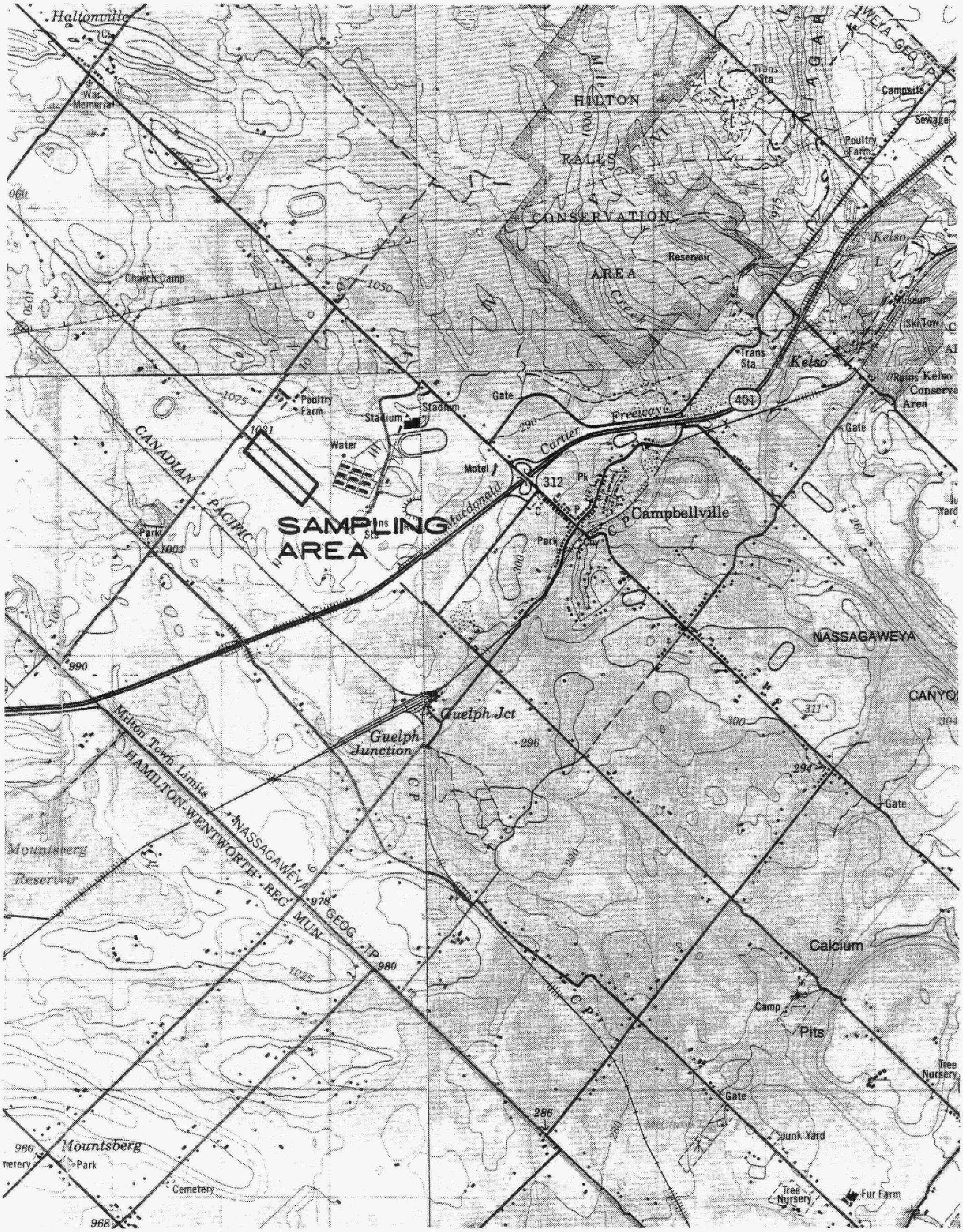


Fig. 5.3

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
MILTON DUST SUPPRESSANT TEST SITE

ACRES

(a) SITE, FACING NORTH

(b) SITE, FACING SOUTH

PLATE 5.3

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
MILTON SITE

ACRES

is familiar and distinctive. By the last visit to the site it had diminished considerably but was still identifiable. Through the years of applications, the road has developed an almost asphalt-like appearance on much of its surface.

The composition of the vegetation in the roadside ditches is given in Table 5.1. On the west side of the road, the test section borders rural residential properties. For the east, there is a broken hedgerow of lilac, poplar and other brush and a pasture not used during any site visits.

5.4 - Armour Township (Crankcase Oils)

In consultation with the Ministry, a supplier from central Ontario was selected as having the wastes designated as 'crankcase oils'. A number of candidate roads were identified and examined. Finally, Jack Lake Road was selected [Figure 5.4, Plates 5.4(a), (b)]. The road is located about 5 km northeast of Burk's Falls. Traffic along the road includes typical rural traffic, cottagers for Jack and Pickerel Lakes and tourists from a large recreation lodge on Pickerel Lake. It was difficult to find a section of road with completely open exposures on both sides. The selected area was open to a residential property on the north side. To the south, there was a broken tree line about 20 m from the road. Jack Lake lay another 80 m to the south through light bush.

The road was found to be quite similar in odor and appearance to the Milton site, except that the application rate was apparently either lighter, or the period of application had been shorter. The road did not have the asphalt-like appearance of parts of the road at Milton.

Roadside vegetation was sparse as identified in Table 5.1.

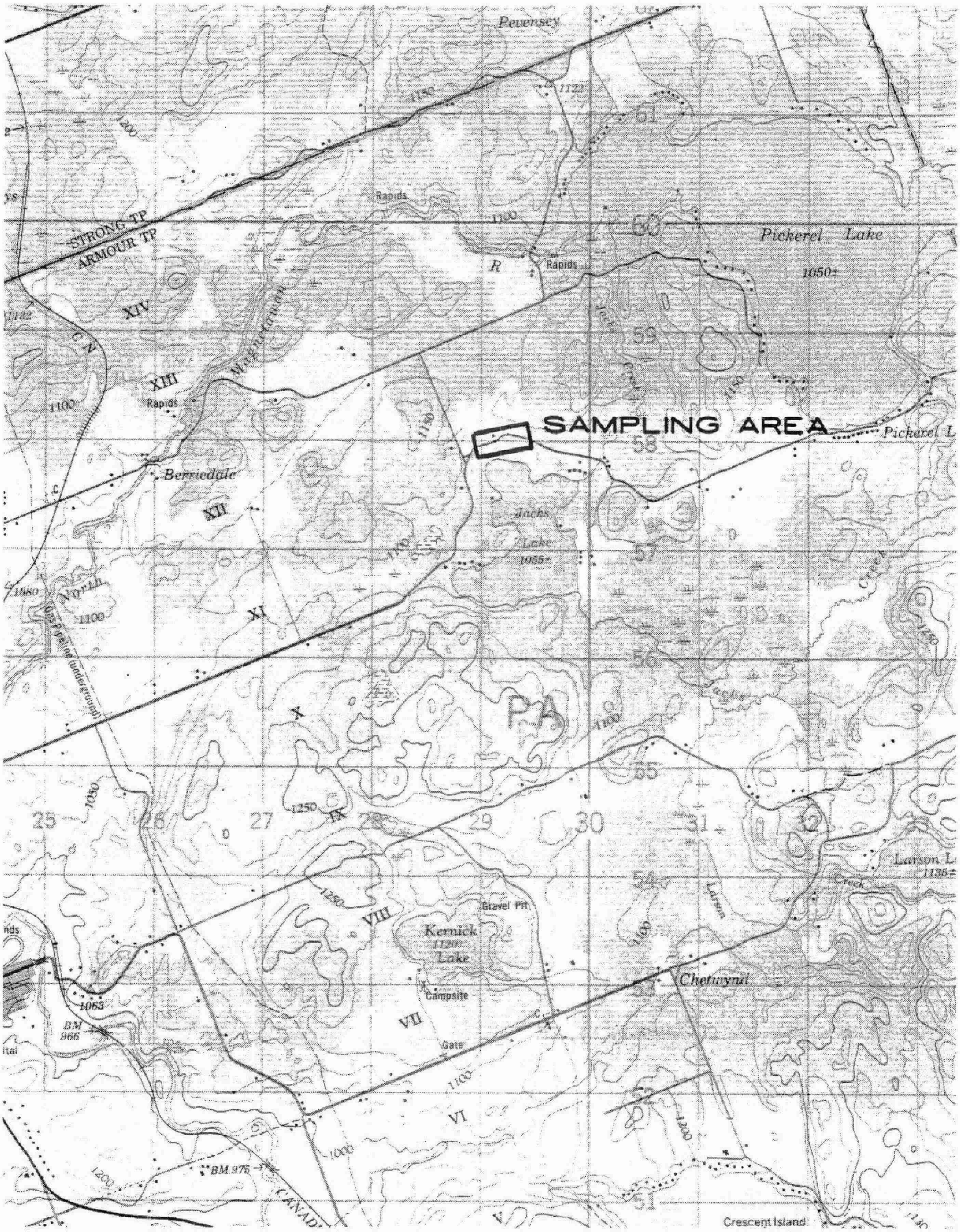
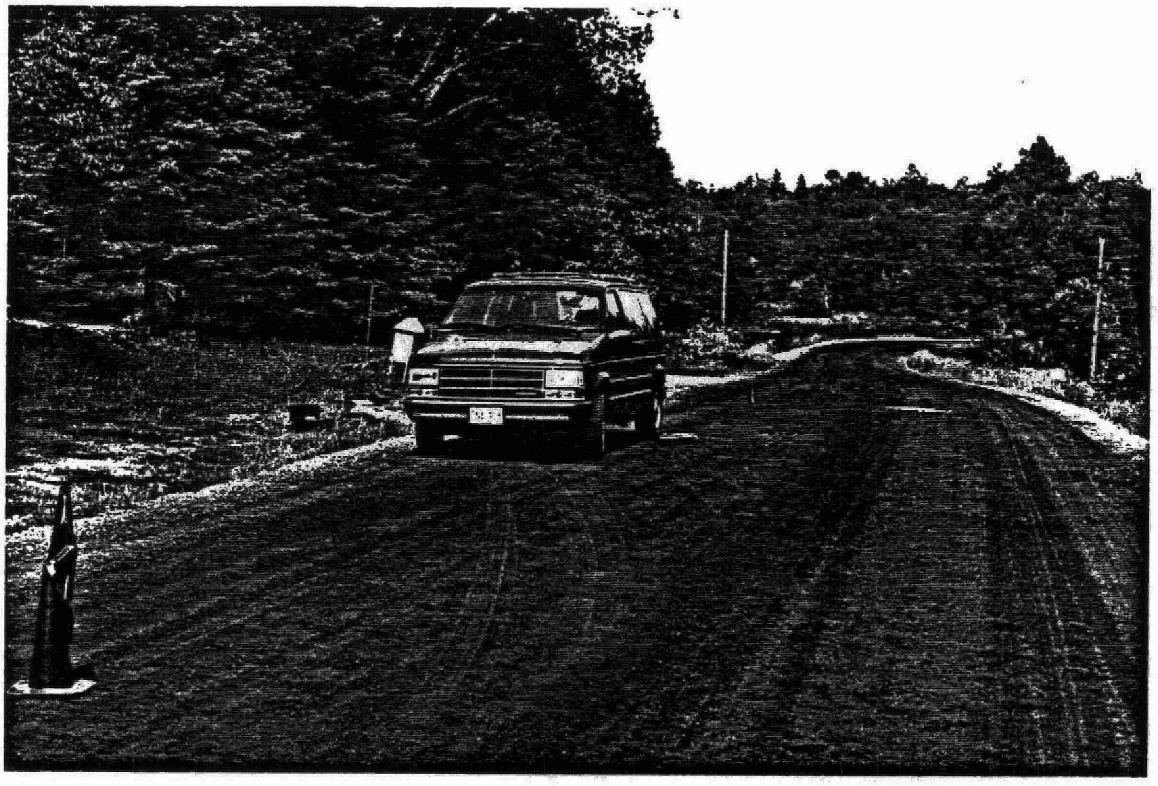


Fig. 5.4

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
ARMOUR TOWNSHIP DUST SUPPRESSANT TEST SITE

ACRES



(a) SITE, FACING EAST

(b) SITE, FACING WEST

PLATE 5.4

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
ARMOUR SITE

5.5 - Coleman Township (Tembind)

Tembind is a proprietary formulation produced from waste pulping liquor by Temfibre in Temiscaming, Quebec. Applications have been made for short test purposes in many parts of the province; however, we could not identify any locations where it had been used on a long-term basis. The Township of Coleman was identified as having used Tembind for two years. The road selected for testing was Marsh Bay Road, approximately 6 km from Cobalt [Figure 5.5, Plates 5.5(a), (b)]. On the west side of the road were several residences. On the east was a field used as a farm airstrip which was becoming overgrown with brush.

The dust suppressant had a similar odor to the Domtar lignosulfonate, but did not appear to have been applied as heavily. There was a similar odor during the first visit (about 1 week after application), but the odor was almost undetectable by the end of the season.

The vegetation in the roadside ditches was relatively sparse and is identified in Table 5.1. The soil was sandy with very little organic matter.

5.6 - Blandford-Blenheim Township (Salt Brine)

Salt-brine is a local dust suppressant produced as a by-product of gas wells in south-western Ontario. The road selected for study was in Concession 10 in Blandford-Blenhein Township, east of Woodstock as shown in Figure 5.6 and Plates 5.6(a) and (b). The road runs east-west and carries typical rural traffic. On the north side, there is a farm with pasture to the north-east and tree seedlings to the north-west. To the south, there is an Oxford County Ministry of Natural Resources Agreement Forest. Vegetation in the roadside ditches is identified in Table 5.1. The road did not show direct evidence of dust suppressant application except at the beginning and end of the application zones where slight darkening of the treated area was observed.

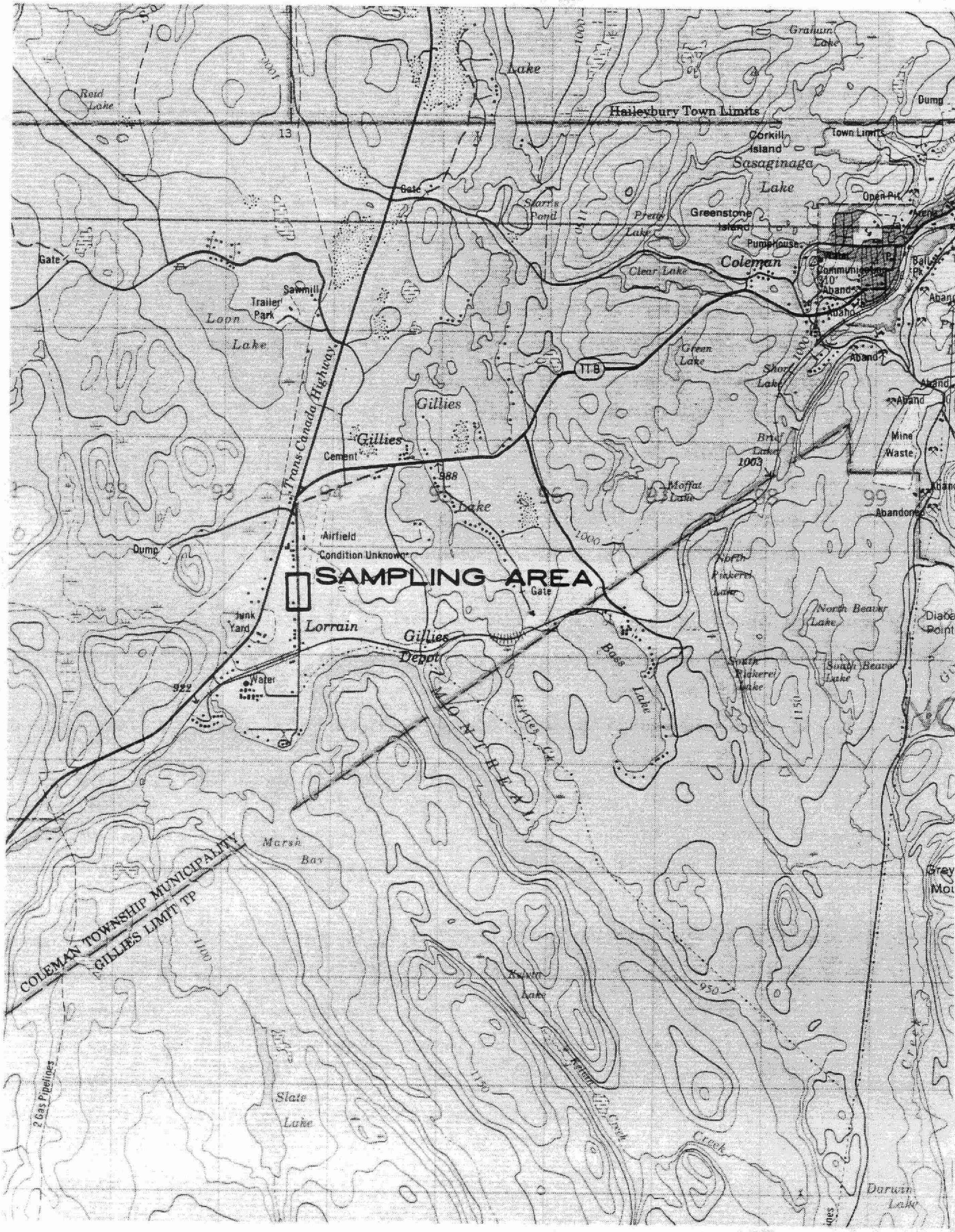
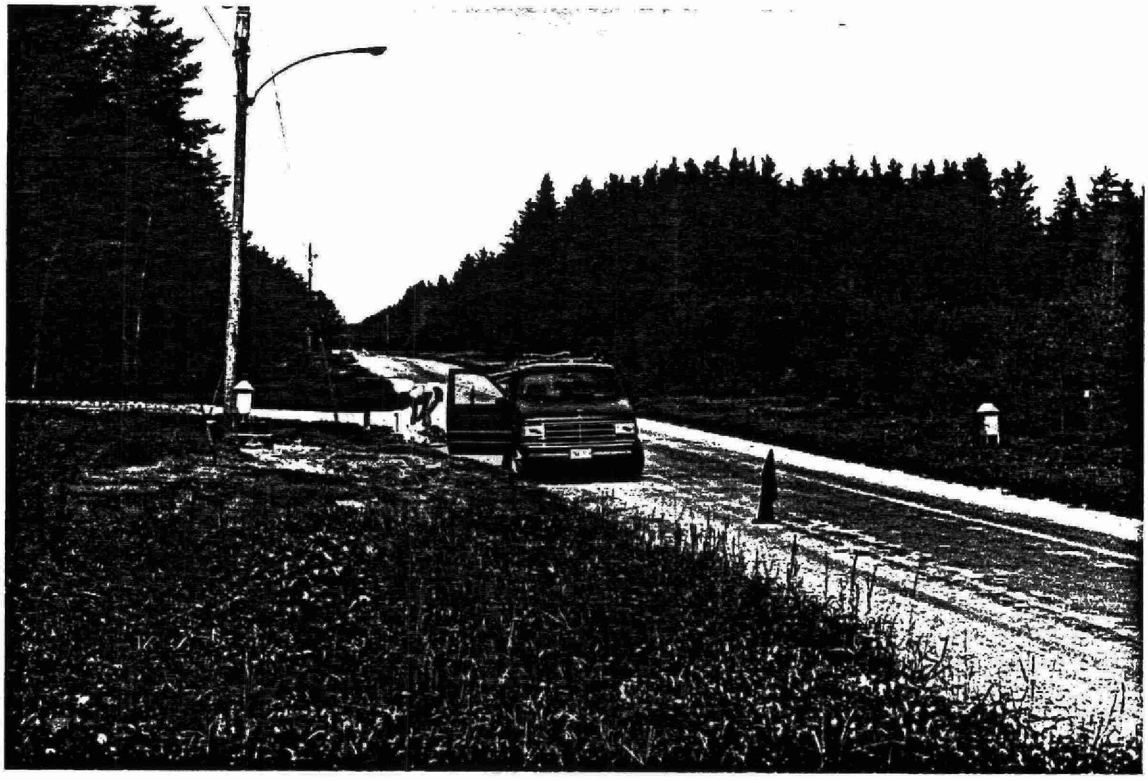


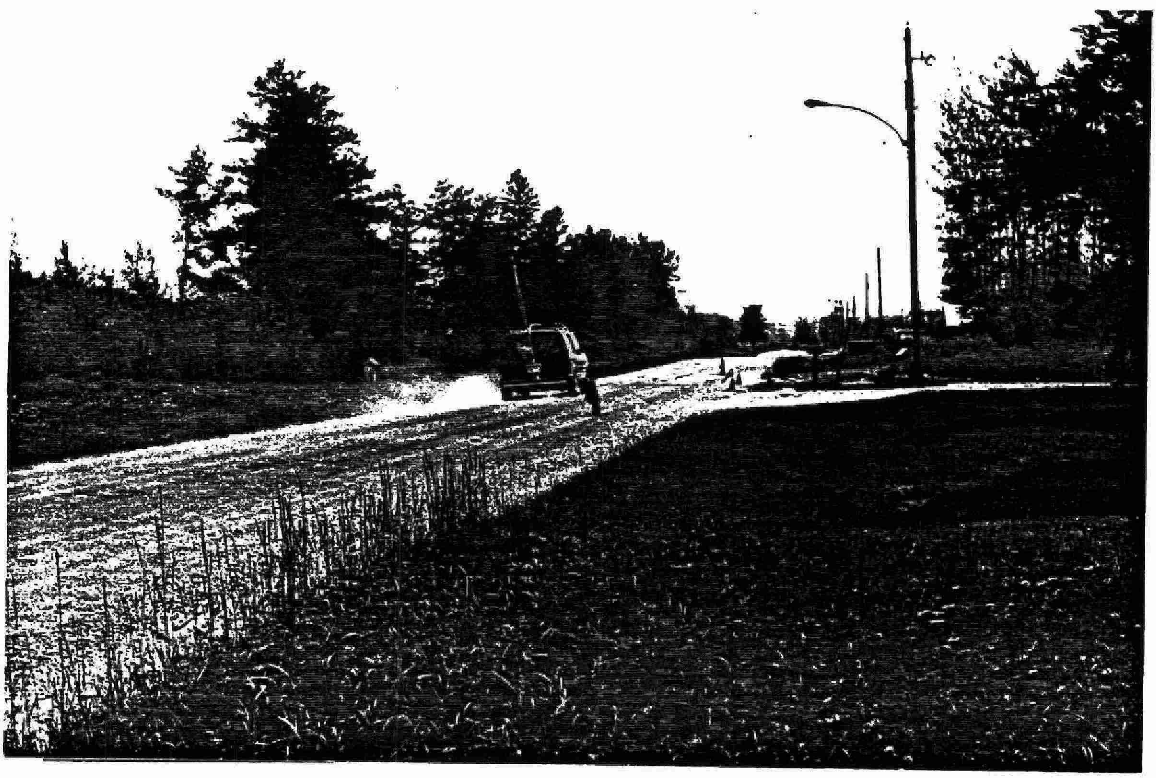
Fig. 5.5

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
COLEMAN TOWNSHIP DUST SUPPRESSANT TEST SITE

ACRES



(a) SITE, FACING NORTH



(b) SITE, FACING SOUTH

PLATE 5.5

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
COLEMAN SITE

ACRES

Fig. 5.6

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
BLANDFORD - BLENHEIM DUST SUPPRESSANT TEST SITE

ACRES

(a) SITE, FACING EAST

(b) SITE, FACING WEST

PLATE 5.6

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
BLANDFORD-BLENHEIM SITE

ACRES

6 - SAMPLING SCHEDULE

6 - SAMPLING SCHEDULE

Table 6.1 lists the dates on which all the components of the field sampling, experiments and monitoring were performed.

The sampling intervals vary slightly from one site to another because of scheduling compromises made because of adverse weather, equipment problems and so forth.

TABLE 6.1

SAMPLING DATES

	NOTL	Picton	Milton	Jack Lack	Coleman	Woodstock
Site Selection	870520	870525	870520	870625	870624	870529
Install Dustfall Jar Set 1	870522	870525	870529	870625	870624	870630
Road and Soil Sampling	870522	870525	870529	870625	870624	870630
Mobile Experiment Set 1	870618	870620	870619	870625	870624	870630
Exchange Dustfall Jars	870721	870719	870722	870726	870725	870723
Mobile Experiment Set 2	870721	870719	870722	870726	870725	870723
Exchange Dustfall Jars	870824	870830	870901	870826	870827	870825
Mobile Experiment Set 3	870824	870830	870901	870826	870827	870825
Collect Dustfall Jars	871014	870928	871006	871001	871002	871005
Road and Soil Sampling	871014	870928	871006	871001	871002	871005
Mobile Experiment Set 4	871014	870928	871006	871001	871002	871005

7 - RESULTS OF DUST MONITORING PROGRAMS

7 - RESULTS OF DUST MONITORING PROGRAMS

7.1 - Dustfall Sampling Results

7.1.1 - Niagara-on-the-Lake (Calcium Chloride)

The number of samples successfully obtained at the Niagara-on-the-Lake site ranged from five in June, July and August to two in September. The collector losses in September were attributed to accidental damage during preparations for the grape harvest. The results are shown in Figures G.1(a) to (d). Levels greater than the provincial standard of 7.0 $g/m^2/30$ d were found at the down-wind roadside location on all four months. Upwind and downwind levels farther from the road were also close to this value for the June through August samples, but none exceeded 12 $g/m^2/30$ d.

The nomenclature of "upwind" and "downwind" that was used for sampler installation is based on the statistical frequency of wind direction. Over a relatively short time period such as the dustfall sampling interval, the wind may not prevail in these directions. The results of this study for Niagara-on-the-Lake and some other sites show that the upwind collectors sometimes had higher dustfall than those downwind of the road. Because this occurred at several sites, it is dealt with in the summary discussion in Section 7.1.7

7.1.2 - Hallowell (Lignosulfonate)

The results of the dustfall monitoring, shown in Figure G.2, confirm the comments by local residents that the area is "dusty". A high level of over 50 $g/m^2/30$ d was observed at the downwind side of the road, and only about one-third of the eight collectors up to 32 m from the road showed less than the provincial standard (7.0 $g/m^2/30$ d) during the four study months.

Levels immediately downwind of the road were consistently highest, but upwind levels were sometimes higher than the downwind counterpart.

7.1.3 - Milton (Industrial Waste Oil)

Milton was noted by the sampling crew as being the least dusty of the experimental sites. Only one application of oil was made in mid-May. Results are shown in Figure G.3. The first set of results through June found less than 3 $g/m^2/30$ d at all sampling points. Levels were highest in July, with levels at about 22 $g/m^2/30$ d for the roadside collectors and falling to about 13 in August. In September, only the two downwind collectors exceeded the provincial standard at 10 to 17 $g/m^2/30$ d.

7.1.4 - Armour (Crankcase Oil)

Dust was well-controlled at Jack Lake and was less than 12 $g/m^2/30$ d throughout the study (Figure G.4). Levels at the collectors were typically about 6 $g/m^2/30$ d. The 2-m high upwind collector had slightly higher levels than its downwind counterpart, but this may have been the result of a clearer exposure.

7.1.5 - Coleman (Tembind)

The results at Coleman are shown in Figure G.5. The collectors at 1.5-m height showed a definite consistent pattern of dustfall--higher on the downwind side and decreasing farther from the roadway. The higher collector on the west side was higher each month, reaching about 53 $g/m^2/30$ d in July when the other collectors received 6 to 24 $g/m^2/30$ d.

The dust was significantly lower in August and September when all collectors received less than 11 and 9 $g/m^2/30$ d respectively. Levels away from the roadside were within the provincial standards.

7.1.6 - Blandford-Blenheim (Salt Brine)

The site near Woodstock gave the impression of being the dustiest site, but the lower traffic volume on the road has reduced the evidence of this in the dustfall monitoring. Dustfall shown in Figure G.6 decreased from July through September from the roadside high over 32 to less than 8 $g/m^2/30$ d.

In July, all eight collectors registered more than the provincial standard, 5 in August and only one in September.

7.1.7 - Dustfall Summary

The geometric means for the dustfall (in $g/m^2/30$ d) are

	June	July	August	September	(3-mo. Av.)
NOTL	5.9	7.6	10.3	5.8	7.7
Hallowell	20.9	18.9	9.6	14.9	13.9
Milton	2.0	15.7	7.4	3.7	7.5
Coleman	N/A	13.9	4.1	4.8	6.5
Armour	N/A	4.6	6.9	4.4	5.2
Blandford-Blenheim	N/A	14.2	10.1	3.9	8.2

The final column is calculated for July, August and September for which data were available for all sites. Since the months during which the study took place are probably the dustiest of the year, the inference could be made that the annual average would be lower in all cases. The absolute magnitude shows that the dust generation is relatively well controlled but with little margin. This agrees with the perception of local residents at all sites who expressed concern about the problem but described it only as severe during occasional episodes. Although it was impossible to find untreated sections of otherwise identical road, isolated gaps in treatment at corners and intersections were noticed and the increased generation of dust in those areas was very

apparent. Discussions with many of those responsible for suppressant application suggested that the applications were made to eliminate public complaints or to reduce them to a reasonable level. The results of this monitoring suggest that the provincial standard is well based and that those responsible for suppressant application have found a maintenance program that generally meets their objectives. Hallowell Township appears to be higher over the 3-month geometric mean, but this is largely due to the significantly higher results of September.

Within the sites, the variation between individual samples requires consideration. As stated previously, the samplers have a designation of upwind or downwind based on wind statistics. The wind rose is not directly convertible into a pollution rose however, especially for sampling periods of one month when the observed wind directions may differ significantly from the long-term prevailing wind directions. The strength of the particulate source may vary because wind direction and strength are correlated with weather conditions; that is, winds from a certain direction do not contribute if they follow a dust controlling shower. Winds from an infrequent direction may contribute significantly if they are from a particulate source other than the road. The wind affects the strength of the road as a particulate source in two ways. First, it acts as a causal agent by directly generating wind blown dust. Second, it acts as a transporting and diluting agent. In this respect it has the reverse effect for dust generated by passing vehicles. In still wind conditions, the plume behind the vehicle will be more concentrated and will move more slowly past the collectors. Thus this component of the total dustfall will vary inversely as the windspeed and the wind generated component will vary directly.

Local topography and the presence of any hedgerows, structures or the like will have a strong effect on the local deposition patterns, particularly during those times when the wind is lightest.

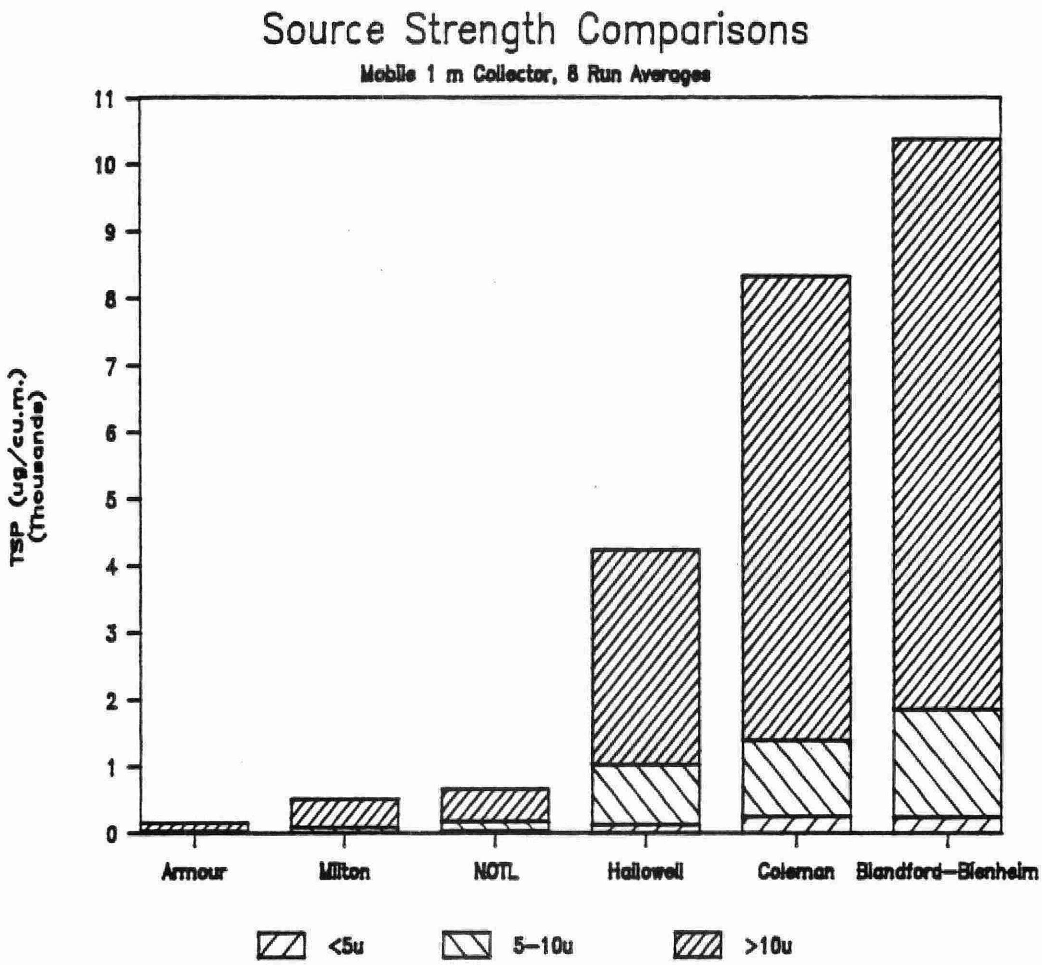
The combination of all of these problematic effects led to the development of the source strength experiments using the moving vehicle and the mobile and fixed collectors. The results of these studies are essential to the objectives of this study and are discussed in the following section.

7.2 - Vehicular Dust Generation Experiments

As discussed in Section 4.5, a series of controlled experiments was designed to evaluate the strength of the road surfaces at the sites as sources of particulates. During each of the four visits to the six sites, two experimental runs were conducted. Hi-vol samplers were stationed on the upwind and downwind sides of the roadway and were operated through the two runs. The upwind and downwind hi-vol results, and the particle size loadings downwind and at 1 and 3 m in height behind the moving vehicle are shown in Figures H.1 to H.6 in Appendix H. The upwind and downwind hi-vols show in all cases an augmentation of the total suspended particulates across the road.

The collector 3 m above the road behind the vehicle obtained sample loadings which were mostly very similar to the collector located at the downwind hi-vol. This confirms that this sampler was generally above the plume generated by the vehicle. The collector 1 m high behind the vehicle received by far the greatest loadings. Visual impressions of the sampling procedure also were that the collector was in the strongest part of the plume. Crosswind components were seldom very strong so the plume was seldom deflected to the side of the sampler, but it is recognized that some variations in the results are due to such affects. The size distribution for this collector shows that it is weighted toward the larger particle sizes, as would be expected close to a mechanical source. The hi-vol readings on the downwind side show levels of about 200 ug/m^3 and less for most experiments, but levels at Blandford-Blenheim (salt brine site) exceeded 1000 ug/m^3 in July and August. Blandford-Blenheim was also judged consistently in the visual ratings to have the least degree of dust control.

The 1 m high collector readings are measures of the strength of the dust source. The eight sets of results from each site were averaged and are shown with the parts in each size range in Figure 7.1. It should be emphasized that these results reflect the frequency of application and road condition and composition in addition to the performance of the suppressant. Figure 7.2 shows the variation and average of the 8 runs. Nevertheless the oil and $CaCl_2$ would seem to be significantly better agents for dust control. These results are quite consistent with the observations of the field personnel.

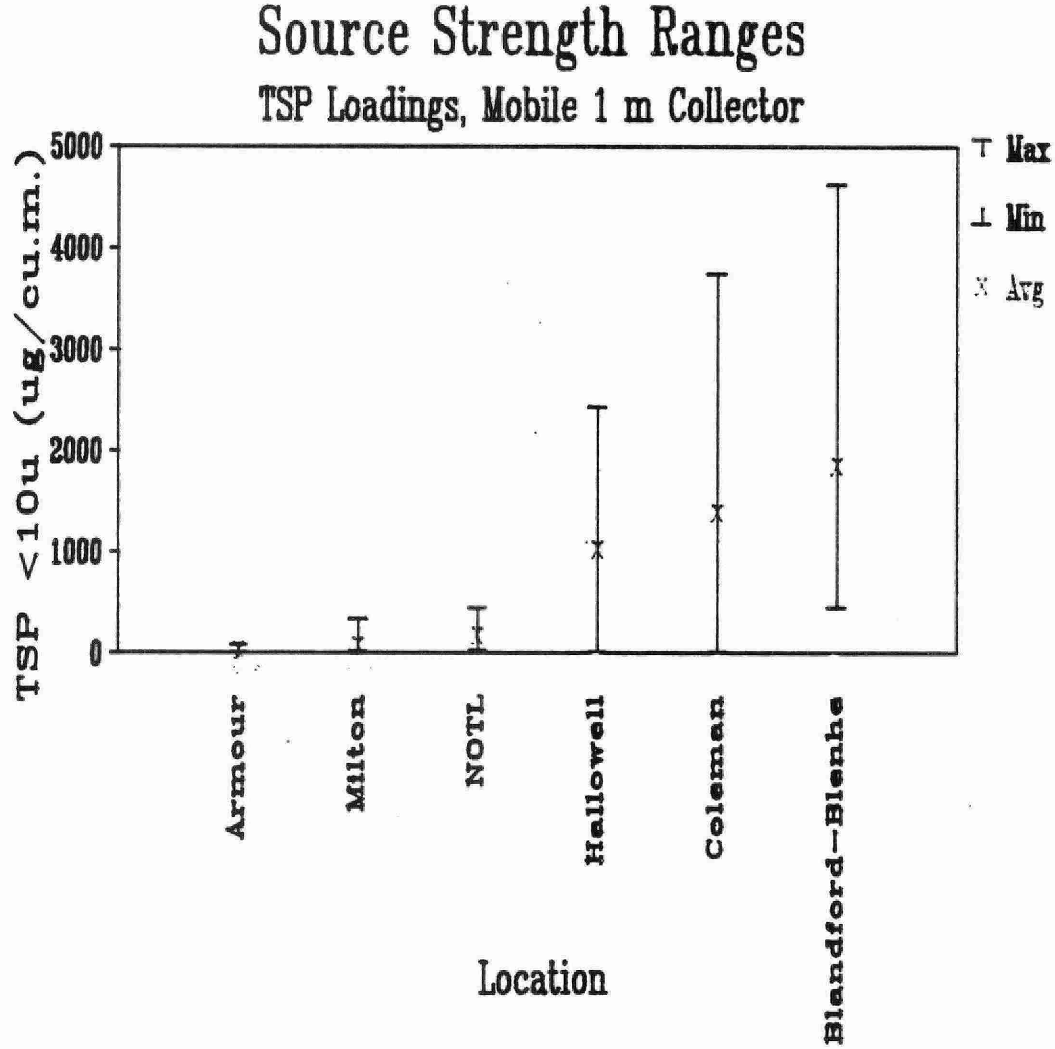


SUPPRESSANTS SITE

Armour	- Crankcase Oil
Milton	- Mixed Oil
NOTL	- Calcium Chloride
Hallowell	- Lignosulfonate
Coleman	- Tembind
Blandford-Blenhein	- Salt Brine

Fig. 7.1

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
SOURCE STRENGTH COMPARISONS WITH SIZE DISTRIBUTION



SUPPRESSANTS SITE

Armour	- Crankcase Oil
Milton	- Mixed Oil
NOTL	- Calcium Chloride
Hallowell	- Lignosulfonate
Coleman	- Tembind
Blandford-Blenhein	- Salt Brine

Fig. 7.2

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
SOURCE STRENGTH RANGES

8 - CHEMICAL CHARACTERIZATION

8 - CHEMICAL CHARACTERIZATION

8.1 - Suppressants

Samples of several types of dust suppressants were analyzed by ICP and other methods for major, minor and trace elements and specific organic components including PCBs. These data are given in Table 9.1.

In order to gain some perspective into the significance of the concentrations of the various analytes tested, a comparison is made in Table 8.1 of the dust suppressant element concentration to the average concentration of that element in the earth's crust. This provides a very gross estimation of potential enrichment, as compared to other elements in the dust suppressant. A comparison is also made, where data is available, with Ontario Ministry of the Environment Regulation 309 Schedule 4 Leachate Quality Criteria. Values given in Table 8.1 are ten times the Schedule 4 limits (drinking water standards) and represent the concentration according to Regulation 309, at which registration of the material producing the leachate would be required. This comparison provides a gross estimation of the relative environmental significance of each element. The ten times Schedule 4 limits are somewhat more conservative than previous studies (i.e. Gillham et al (1985) used 100 times), however Regulation 309 was not in existence at that time. In any event, there are no other guidelines in existence with which to compare these materials.

8.1.1 - Calcium Chloride

Except for Ca, the major cationic component of $CaCl_2$, 35% solution, all the other components were found in quantities less than average crustal abundance and less than or equal to Schedule 4 concentrations. The detection limits for Tl and Hg were not low enough to allow this comparison to be made. Both elements,

TABLE 8.1

CHEMICAL ANALYTICAL DATA OF DUST SUPPRESSANTS
COMPARED TO CRUSTAL ABUNDANCE AND MOE REG 309 SCHEDULE 4

	Crustal Abundance (mg/kg)	MOE Reg309 Sched. 4 X10 (mg/kg)	NOTL 35% CaCl2 (mg/kg)	Coleman Tembind (mg/kg)	#1498 Coherex (mg/kg)	Woodington Bond-All (mg/kg)	RFS#2994 Coherex (mg/kg)	Hallowell Ligno-sulfonate (mg/kg)	Blandford-Blenheim Salt Brine (mg/kg)	Waste Oil A (mg/kg)	Milton Waste Oil B (mg/kg)	Armour Waste Oil C (mg/kg)	Waste Oil D (mg/kg)
Ca	36 300		170 000	420	330	1 600	290	370	25 000	4 100	130	450	960
Mg	20 900		6.5	120	70	520	61	87	2 800	980	19	78	230
Na	28 300		4 700	30	170	65	100	27 000	17 000	1 200	<20	50	650
K	25 900		400	340	<40	<40	<40	920	330	<40	<40	<40	<40
Al	81 300		5.8	<5	<5	<5	<5	<5	<5	<5	220	110	<5
Ba	425	10	10	0.59	0.68	1.4	0.59	6.3	0.45	14	9	11	1.7
Be	2.8		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
B	10	50	3.9	<1	<1	21	<1	8.3	1.3	23	6.4	8.5	<1
Cd	0.2	0.05	<0.2	<0.02	<0.2	0.84	<0.2	<0.2	<0.2	1.4	<0.2	1.8	<0.2
Cr	100	0.05	<1	<1	<1	<1	<1	<1	<1	7.2	5	5.6	<1
Co	25		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cu	55		<1	<1	1.1	60	<1	<1	<1	46	23	<1	12
Fe	50 000		<1	16	21	160	28	14	<1	140	410	250	34
Pb	13	0.5	<5	<5	<5	35	<5	<5	<5	1 400	400	820	<5
Mn	950		<1	46	<0.5	110	<0.5	6.8	23	220	13	65	<0.05
Mo	1.5		<1	<1	<1	<1	<1	<1	<1	7.2	<1	4.8	<1
Ni	78		<1	<1	9.2	<1	<1	<1	<1	7	4.1	1.6	2.5
P	1 050		<10	<10	<10	1 100	<10	30	<10	1 060	620	730	<10
Si	277 200		<5	12	32	45	<30	34	<5	190	56	110	59
Sr	375		26	1.6	1.2	2	0.86	1.5	610	13	1.1	1.1	3.7
Tl	0.5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ti	4 400		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
V	135		<1	<1	19	<1	<1	<1	<1	<1	6.3	2.6	<1
Zn	70		<1	<1	1.3	1 200	<1	3.1	<1	1 200	220	610	<1
Zr	165		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mercury	0.08	0.01	<0.5										
Tri.C.E						<1				<1	<1	3.1	<1
Tet.C.E						<1				<1	39.4	40.4	<1
PCB		0.03				<1	<1			<1	<1	494	<1
Se				5	<5		<5	<5					

however, are not environmentally significant at these low concentrations, especially in the presence of extremely high Cl concentrations.

The main environmentally significant characteristic of $CaCl_2$ is its extremely high water solubility. This allows it to make available to the environment highly mobile ions of Ca, Mg, Na, K and Cl, and possibly SO_4. High ionic strength waters resulting from runoff have the potential to cause salt-effect damage to vegetation and increases in salinity of receiving waters, including local groundwater.

Further studies are required to determine the fate of the (low concentrations) of heavy metals associated with the $CaCl_2$. Initially, prior to significant dilution, most of the metals would form charged chloride complexes. With dilution, metals may be released in more available form. Mercury for example would exist as $HgCl_4^{2-}$ in the 35% $CaCl_2$ solution. With dilution (down to pCl = 1 M) the predominant mercury complex would convert to $HgCl_3^-$, then $HgCl_2^o$ (available for uptake by aquatic fauna) then, depending on pH and further dilution, HgOHCl and finally $Hg(OH)_2^o$ (and under very acidic conditions, $HgCl^+$). Conceivably, the amount of dilution required to convert the mercury to the neutral chloride complex available for fish uptake could readily occur where roadside ditches enter small streams.

The theoretical mole percent of Ca in $CaCl_2$ is 36.11%. Therefore, in a 35% solution, Ca concentration should be about 12.6% or 126,000 mg/kg. From Table 8.1, the Ca concentration is 170,000 mg/kg.

8.1.2 - Salt Brine

Table 8.1 depicts analytical data for the salt brine sample supplied for this study. The analysis shows that this material is a Ca-Na salt solution of approximate cation concentration of

45,800 mg/kg with a Ca:Na of 1.47 (i.e. Ca is the major cation). Except for K, whose concentration is somewhat lower, all parameters tested were found in concentrations similar to those found for salt brine in the study by Gillham, et al (1985).

Assuming Cl is the major anion, the theoretical concentration of this solution is 6.5% $(Ca\text{-}Na)Cl_n$. This is in comparison to $CaCl_2$ which is typically supplied at a nominal strength of 35%.

The detection limit for Cd is not sufficiently low to compare salt brine Cd concentrations to crustal abundance. However, Cd is not likely to be environmentally significant at this concentration in the presence of abundant chloride. All other measured components were found to be below crustal abundance except Sr. At 610 mg/kg Sr was almost double crustal abundance. This is not considered significant, however since Sr is typically >600 mg/kg in carbonate rocks and >1000 mg/kg in feldspars (crustal abundance data is generally based on Sr-poor granites and basalts). Sr commonly substitutes for chemically similar Ca in the salt crystal lattice because of similar ionic radii (G=0.99 A, Sr=1.12 A).

Like $CaCl_2$, from the analysis presented here, salt brine would be expected only to cause ionic strength and other salt related effects on the environment. It cannot be predicted what affect the release of heavy metals from the solution (with dilution) would have downstream of the dust suppressant application area.

8.1.3 - Road Oils

Four road oils, also known as waste oils, and an emulsified oil formulation were analyzed for major, minor and trace metals, tri and tetrachloroethylene and PCBs (see Table 8.1).

The chemical analysis indicates that the sample labelled Waste Oil D is not representative of a waste oil. This sample contains

undetectable amounts of typical waste oil contaminants such as B, Cd, Pb, P and Zn. The following discussion will exclude reference to this sample.

The four remaining oils have, for the parameters tested, concentrations similar to those found for automobile and industrial oils in the study by Gillham et al 1985. These four road oils were somewhat concentrated in certain heavy metals. In comparing metal concentrations to 10 times MOE Regulation 309 leachate toxicity limits, two samples exceed this limit for barium, three for cadmium, three for chromium, all four for lead and one for PCBs. For testing purposes under Regulation 309, the oils are considered 'leachate' by the MOE. For discussion and comparison purposes, this suggests that if these oils were submitted for leachate toxicity testing according to the regulation all of the samples would fail at least one Schedule 4 criterion. In fact three of the samples would qualify as 'hazardous' under Regulation 309 (i.e., >100 times Schedule 4), because they are leachate toxic with respect to Pb, and the fourth one is leachate toxic with respect to Cd. One sample found to contain nearly 500 mg/kg PCB is ten times over the limit of 50 mg/kg which defines a 'PCB waste material'.

Trichloroethylene and tetrachloroethylene concentrations ranged from <1 to 3.1 mg/L and from <1 to about 40 mg/L respectively indicating that none of the oils are likely being used as a carrier to dispose of these solvents. These trace amounts of TCE are too low in concentration to constitute a significant disposal path for degreasers. At a concentration of 40 mg/kg (and assuming a tank truck carries 10 t of waste oil) this represents about 268 mL of TCE, that is about 1/4 L of TCE per tank truck load.

8.1.4 - Sulfite Liquors and Emulsions

The two sulfite liquor type dust suppressants studied here, Tembind and black liquor, and the emulsion Coherex, are innocuous

in terms of the inorganic constituents studied. Other than one sample of Coherex containing comparatively elevated concentrations of nickel and vanadium, these materials are not likely environmentally significant but may be useful in determining the origin of the materials used in producing the suppressant. The Ni and V in the Coherex are well below average crustal abundance and likely fairly strongly organically chelated in this medium. Further study is required to determine availability of these elements to the natural environment after application.

In comparing the sulphite liquor type materials to those studied by Gillham et al (1985), except for Zn which is slightly higher in the black liquor in this study, all other parameters tested in common were of similar concentration range.

8.2 - Surficial Materials

Data from the analysis of surficial materials for each road dust suppression study area are given in Tables 8.2 to 8.7. Also listed for comparison purposes are the Ontario Ministry of the Environment contaminant guidelines representing upper limits of normal concentrations of metals (Cd, Cr, Cu, Pb, Ni, Zn, Mn, B and Se) in soil. Average crustal abundances are given for Ag, Ba and Cl. Background PCBs in soil and vegetation will be assumed here to be 0. Metal concentrations for upper limits and average crustal abundance are "total" metals, whereas data presented here are for non-residual metal or cold-acid-soluble metal. Residual metal does not represent intramolecular silicate lattice bound metals. The difference is largely academic since most metals in soils are adsorbed to particulates and organic matter, and especially in the case of Southern Ontario carbonate based soils, carbonate lattice bound metals are readily released by the cold-acid digestion. Therefore, a direct gross comparison can be made between these data and the MOE upper limit and average crustal concentrations.

TABLE 8.2

NIAGARA-ON-THE-LAKE-$CaCl_2$

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of Normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	0.3 - 0.4	0.2 - 0.4	0.2 - 0.4	0.5	0.3 - 1.2	<0.2
Cr	50	1.2 - 1.5	<0.5	<0.5 - 0.6	5	3.1 - 6.4	<1
Cu	60	3.3 - 9.8	0.5 - 0.7	0.6 - 1.7	7	4.9 - 18.4	<1
Pb	60	10 - 14	3	3 - 6	20	5 - 32	<5
Ni	32	2.9 - 4.7	0.5 - 1.3	0.6 - 2.5	5	10 - 22.1	<1
Zn	220	2.2 - 9.5	2.3 - 4	1.8 - 4.6	40	4.9 - 18.4	<1
Mn	700	664	56 - 71	225	50	75	<1
B	10	<50	<50	<50	20	<200	3.9
Ba	425[1]	55	5 - 6	24	14[2]	46	10
Cl	130[1]	60 - 200	400 - 1820	130 - 410	10 000	2650 - 4900	

Road Materials - Chloride (mg/kg)

Sample Location	Sample 1	Sample 2	Sample 3
Depth 0 - 10 cm	1690	1820	1770
10 - 20 cm	720	480	400

[1]Average crustal abundance.

[2]Typical literature values.

TABLE 8.3

BLANDFORD-BLENHEIM - SALT BRINE

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of Normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	<0.1 - 0.3	0.3 - 0.4	0.3 - 0.5	0.5	<0.1	<0.2
Cr	50	<0.5 - 0.7	<0.5	<0.5	5	<0.5 - 1.8	<1
Cu	60	1 - 1.7	<0.3 - 0.7	0.3 - 0.6	7	3.3 - 6.1	<1
Pb	60	8 - 13	<0.5 - 5	<5	20	<5	<5
Ni	32	1.4 - 3.1	2.2 - 2.4	2.6 - 3.8	5	4.0 - 24.5	<1
Zn	220	0.6 - 49	0.4 - 2.3	2.9 - 9.8	40	<0.5 - 34	<1
Mn	700	58	56 - 71	171	50	75	23
B	10	<50	<50	<50	20	<200	1.3
Ba	425[1]	15	5 - 6	12	14[2]	46	0.45
Cl	130[1]	60 - 100	120 - 4300	70 - 210	10 000	7100 - 18400	

Road Materials - Chloride (mg/kg)

Sample Location		Sample 1	2	3
Depth	0 - 10 cm	1270	1630	4300
	10 - 20 cm	190	120	220

[1]Average crustal abundance.

[2]Typical literature value.

TABLE 8.4

MILTON - WASTE OIL B

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of Normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	0.88	0.59 - 0.68	0.71	0.5	1.6	<0.2
Cr	50	<0.5	<0.5	<0.5	-	-	5
Cu	60	0.4 - 3.2	<0.3 - 0.7	<0.3 - 0.5	5	11.4 - 22.2	23
Pb	60	<0.5 - 14	<5	<5 - 7	7	30 - 43	400
Ni	32	1.5 - 2.3	<0.5 - 2.1	1.8 - 2.1	-	-	4.1
Zn	220	0.6 - 11.6	1.7 - 10.8	5.5 - 8.7	40	42 - 64	220
Mn	700	593	118 - 133	220	50	708	13
B	10	<50	<50	<50	20	<50	6.4
PCB	-	<0.02	<0.02	<0.02	-	<0.02	<1

TABLE 8.5

ARMOUR - WASTE OIL C

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of Normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	0.32	<0.1	<0.1	2	0.33	1.8
Cr	50	0.6 - 1.5	0.7 - 0.9	0.9 - 1.9	5	-	5.6
Cu	60	1.8 - 2.4	3.5 - 5.9	3.3 - 5.7	20	4 - 11.5	<1
Pb	60	<5 - 23	<5 - 13	13 - 18	20	<5 - 25	820
Ni	32	0.7 - 2.7	0.8 - 1.2	1.4 - 2.1		-	1.6
Zn	220	4.8 - 22.6	3.9 - 28.1	2.6 - 12.7	100	53 - 79	610
Mn	1000[1]	35	28 - 44	53	50[2]	205	65
B	10	<50	<50	<50	75	<50	8.5
PCB	-	<0.02	<0.02 - 1.3	<0.02	-	<0.02- 0.3	494

Road Materials - PCB (mg/kg)

Sample Location	Sample 1	2	3
Depth 0 - 10 cm	1.30	0.20	0.50
10 - 20 cm	0.10	<0.02	<0.02

---

[1]Northern Ontario Soil Value

[2]Typical literature value.

TABLE 8.6

HALLOWELL - LIGNOSULFONATE

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of Normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	<0.1 - 0.3	0.3	<0.1 - 0.4	-	-	<0.2
Cr	50	1.1 - 1.5	<0.5	0.5 - 0.6	-	-	<1
Cu	60	1.4 - 1.9	<0.3 - 0.6	0.3 - 0.7	-	-	<1
Pb	60	9 - 13	6 - 7	7 - 26	-	-	<5
Ni	32	<0.5 - 2.4	1.6 - 2.3	0.6 - 2.6	-	-	<1
Zn	220	1.2 - 15	0.9 - 2.6	1.3 - 6.8	40	<0.5 - 2.5	3.1
Mn	700	97	47 - 72	107	50	100	6.8
B	10	<50	<50	<50	20	<100	8.3
Ba	425[1]	21	6	17	14[2]	34	6.3
Se	1.6	5.6 - 7.5	<0.1 - 7.5	15.7 - 30.3	.5	30.2 - 10	3.4
Ag	0.07[1]	<0.5	0.5 - 0.8	<0.5 - <0.5	-	-	

[1]Average crustal abundance.

[2]Typical literature value.

TABLE 8.7

COLEMAN - TEMBIND (PULPING LIQUOR FORMATION)

Element	Upper Limit Normal Concentration (mg/kg)	Site Background Soil Levels (mg/kg)	Road Material Levels (mg/kg)	Ditch Material Levels (mg/kg)	Upper Limit of normal Concentration in Grass (mg/kg)	Site Vegetation Levels (mg/kg)	Suppressant Levels (mg/kg)
Cd	1.6	<0.1 - 0.56	<0.1	<0.1	2	0.56	<0.02
Cr	50	0.7 - 1.9	1.9 - 2.8	2 - 3	-	-	<1
Cu	60	2 - 12.7	4.1 - 9.1	6.9 - 12	-	-	<1
Pb	60	<5 - 23	7 - 12	15 - 30	-	-	<5
Ni	32	1.6 - 13.8	3.7 - 4.9	3.3 - 6.5	-	-	<1
Zn	220	5.6 - 31.9	1.4 - 8.4	2.1 - 24.9	100	0.2 - 140	<1
Mn	1000[1]	12	41 - .53	48	50	38	46
Se	1.6	3.5 - 7.7	36 - 6.0	4.1 - 6.5	.5	3.6 - 4.7	5
Ag	0.07[2]	<0.5 - 6.3	0.9 - 2.5	0.7 - 2.8	-	-	

[1]Northern Ontario Soil Value

[2]Average crustal abundance.

Metal concentrations in various types of vegetation vary greatly. Average vegetation metal contents are given as a guide. It is likely that differences must exceed 1 or 2 orders of magnitude to be considered significant.

8.2.1 - Calcium Chloride (Niagara-on-the-Lake, Ontario)

Potential environmental indicator parameters for the $CaCl_2$ study are the elements Cd, Cr, Cu, Pb, Ni, Mn, B, Ba, Zn and Cl. It is not possible here to separate the effects of $CaCl_2$ as a dust suppressant and the effects of road de-icing salt in the various compartments studied.

(a) Background

As shown in Table 8.1, all the elements chosen for study are generally below upper limit or average crust concentration for the background soil samples.

(b) Road Materials

The road materials contain the selected elements at concentrations at or below the concentrations found in the background soils, except for Cl. Cl is concentrated in the surface 10 cm of road material to about ten times background but reduces to two to three times background in the lower 10 - 20 cm. The Cl is likely retained in the road material as salts of Ca and Mg, a direct result of road dust suppressant and road de-icing salt application.

(c) Ditch Materials

Ditch soils, which are receptors of flow from the road surface, are at or below background soil concentration for each element tested except for one sample (from a suite of

3) for Cl. This single sample was about two times more concentrated in Cl than the background soil.

The data indicates generally that Cl is not being retained by the ditch soils. This is likely a result of chloride's extreme mobility resulting from its solubility in association with Ca and Na. Therefore, virtually all of the Cl flowing off the road surface remains in solution and is washed out of the system, ending up in local streams or groundwater.

In poorly drained areas, such as pooled portions of ditches, evaporation would cause residual Cl to precipitate as a salt and deposit in the ditch soils.

(d) Vegetation

The roadside vegetation does not appear to be influenced by $CaCl_2$ application.

8.2.2 - Salt Brine (Blandford-Blenheim)

Potential environmental indicator parameters for the salt brine study area are the elements Cd, Cr, Cu, Pb, Ni, Mn, B, Zn and Cl.

It is not possible here to separate the effects of $CaCl_2$ as a dust suppressant and the effects of road de-icing salt in the various compartments studied.

(a) Background

All the elements chosen for study are below the MOE upper limit or average crustal concentration for the background soil samples.

(b) Road Materials

The road materials have elemental concentrations similar to or below background except for slightly elevated concentrations of Mn and order of magnitude elevation of Cl. This accumulation of Cl, and possibly to a certain extent Mn, is directly related to salt brine or de-icing salt application. The Cl is most concentrated in the upper 10 cm of road and nearby approaches background at the 10 - 20 cm horizon.

(c) Ditch Materials

The elements Cl and Mn are elevated in concentration relative to the background soils; Cl by a factor of up to 2, and Mn by a factor of 3. This is likely an artifact of runoff from the road materials.

(d) Vegetation

The only obvious anomaly in roadside vegetation content is Cl. The vegetation is enriched up to almost 2 times in Cl (above upper limit of normal concentration), likely a direct result of the use of salt brine on the road.

8.2.3 - Industrial Waste Oil (Milton, Ontario)

Potential environmental indicator parameters for this road oil study area are Cd, Cr, Cu, Pb, Ni, Zn, Mn, B and PCBs.

(a) Background

All the elements tested in the background soil were present in concentrations less than upper limits for normal concentration in soils. PCBs were not found at a detection limit of 0.02 mg/kg.

(b) Road Material

The road materials were not enriched in any of the parameters tested, with respect to background soils.

(c) Ditch Materials

The ditch materials were not enriched in any of the parameters tested, with respect to the background soils.

(d) Vegetation

In comparison with upper limit of normal vegetation element concentrations the roadside vegetation was enriched in Cd, Cu, Pb and Mn. This enrichment is not considered significant since the values found here (Table 8.4) are still near typical vegetation in concentration of these elements.

8.2.4 - Crankcase Waste Oil (Armour, Ontario)

Potential environmental indicator parameters for this road oil study area are Cd, Cr, Cu, Pb, Ni, Zn, Mn, B and PCBs.

(a) Background

All the elements tested in the background soil were present in concentrations less than upper limits for normal concentrations in soils. PCBs were not found at a detection limit of 0.02 mg/kg.

(b) Road Materials

None of the target compounds in the road materials were found to be elevated to concentrations over background soils, except Cu and PCBs. It was previously stated that the road oil supplier for this site had experienced PCB

contamination problems with their product. This contamination may be related to the presence of PCBs in the road surfacing materials. The road surface (0 - 10 cm) contained up to 1.3 mg/kg PCBs.

(c) Ditch Materials

Except for a slight elevation of the concentration of Cu and Mn in ditch materials, no other parameters are enriched over background soils in the ditches. The cause of the slight elevations of the concentrations of Cu and Mn has not been determined.

(d) Vegetation

The roadside vegetation appears to be affected by the road oil in terms of Mn and PCBs. Three samples of vegetation were analyzed for PCBs and have concentrations of <0.02, 0.09 and 0.30 mg/kg. Uptake of PCBs can be derived from three mechanisms

- direct deposition by overspray or atmospheric deposition
- direct runoff of excess oil onto the vegetation
- by migration of PCBs from the road surface via aqueous media.

The slight elevation of Mn in the roadside vegetation is not considered significant as it is still below the typical Mn content of vegetation.

8.2.5 - Lignosulfonate (Hallowell Township, Ontario)

Potential environmental indicator parameters for this suppressant are Cd, Cr, Cu, Pb, Ni, Zn, Mn, B, Ba, Se and Ag.

(a) Background

All the elements tested in the background soil were present in concentrations less than the MOE upper limits for normal concentrations, or near average crustal abundance, with the exception of Se.

(b) Road Materials

Road materials have elemental concentrations the same as or less than background soils, except for Ag. This is slightly enriched in the road material. This difference may be the result of gross differences in road material source area to the background soils.

(c) Ditch Materials

The ditch materials, compared with background soils, are enriched in Pb, likely a result of automobile exhaust emissions. Both ditch materials and background soils were also enriched in Se. The ditch materials may be providing better adsorption conditions for Se, in the form of fine particulates or organic matter. The Se is not likely the result of lignosulfonate applications. Black liquor Se concentration was <5 mg/L.

(d) Vegetation

Compared to vegetation analyzed from the Coleman site, the vegetation found here is about an order of magnitude more concentrated in Se. It is also more than an order of magnitude above normal upper limits. This is likely an artifact of the soil conditions described above. The vegetation element content for the tests performed does not appear to be influenced by the application of lignosulfonate to the road.

8.2.6 - Tembind (Coleman, Ontario)

Potential environmental indicator parameters for the Tembind study area are Cd, Cr, Cu, Pb, Ni, Se, Ag, Zn and Mn.

(a) **Background**

All elements tested were below upper limits of normal concentration in soils except Se and Ag which were slightly elevated in the background soils, likely a result of local mineralization. There are numerous silver mines in the area and selenium is present in may silver ores.

(b) **Road Material**

All the elements studies have concentrations in the road materials similar to background soils except Mn. This is about four times more concentrated in the road materials. Of the trace metals analyzed in both the road material and in the supplied Tembind sample, Mn is the only one with a concentration higher than the analytical detection limit. There is insufficient evidence to conclude that the Mn in the road materials is a result of Tembind application.

(c) **Ditch Materials**

The same phenomenon occurs for the ditch materials as for the road materials in terms of Mn enrichment. Pb is also slightly enriched in the ditch materials, likely a result of automobile exhaust emissions.

(d) **Vegetation**

For the elements tested, the vegetation did not appear to be influenced by the Tembind dust suppressant.

8.3 - Impacts and Concerns

8.3.1 - Chloride Type Suppressants

The use of $CaCl_2$ or salt brine appears to have no deleterious effects on the environment except to raise roadside vegetation Cl concentrations. This effect is minor.

8.3.2 - Road Oils

PCB-free road oils appear to have no deleterious effects on the environment. Road oils containing PCBs cause accumulation of PCBs in the road surface and in roadside vegetation. Although not shown in this study, accumulation of PCBs could occur in roadside ditch soils.

8.3.3 - Lignosulfonates

Neither the Coleman nor Hallowell sites revealed any significant impacts nor concerns.

9 - SURVEY OF APPLICATION PRACTICES

9 - SURVEY OF APPLICATION PRACTICES

9.1 - Survey of Road Authorities

The six participating road authorities were each sent a survey form as shown in Appendix I. Responses were received from Milton, NOTL, Hallowell, Coleman and Blandford-Blenheim. We were unable to obtain a response from Armour township in time for inclusion into the report. Information pertaining to costing and application rates was obtained from the township's oiling contractor for 1987.

9.2 - Survey Results

Each township tends to favor the dust suppressant used in their respective township. Responses seem to be biased to reflect these tendencies. Most criticisms about suppressants came from townships not using that particular suppressant.

Milton, Hallowell and Coleman all reported side benefits associated with the suppressants used in their townships. A reduction in road maintenance was noted by each. Milton and Hallowell both reported a 50% reduction in grading frequency.

All the townships but Hallowell rely on contractors to supply and apply the dust suppressants. Hallowell uses its own trucks and personnel for application. The proximity to the supplier (Domtar), and the fact the lignosulfonate is free, makes this practice practical. This situation is unique to areas where the pulping liquor is available. The ratio of machinery use for dust suppressant application versus other use is approximately 28%. While not applying dust suppressants, the machinery and labor are used for other maintenance duties all of the time. This allows the township to operate their own dust suppressant application with minimal overhead.

There is a mixed response pertaining to how and why the suppressant was chosen for each township. Two of the townships (Hallowell and Coleman) relied on council to choose the suppressant while NOTL and Blandford-Blenheim relied on the town or road superintendent. Milton did not indicate the party responsible for choosing their dust suppressant. Blandford-Blenheim and Milton chose the dust suppressant primarily based on cost while Hallowell and Coleman indicated an evaluation process was used based on performance. NOTL chose $CaCl_2$ because it is easy to use and they found there were maintenance savings caused by its use.

The final section of the survey requested an evaluation of 8 different dust suppressants from each of the townships. All the townships, with the exception of NOTL, indicated that $CaCl_2$ was too expensive. The townships' concerns with road oil were based on environmental problems. NOTL and Hallowell also reported that road oiling can cause dangerous, slippery road conditions and extra road maintenance. Road maintenance problems listed included grading and pothole patching (cold patching). It is interesting that although these townships believe there are grading problems, Milton reports a 50% decrease in grading requirements caused by use of road oil.

Only two townships responded to the pulping liquor section. Milton did not favor it because of poor performance and strong odor. Hallowell, which uses pulping liquor, responded favorably to the dust suppressant. They are satisfied with its performance, cost and its environmental effects. The lack in response could be due to the availability of pulping liquor and the proximity of the townships to a source.

Two townships commented on the use of Tembind. Milton tried a test section in 1984 and found its performance to be unsatisfactory while Coleman was satisfied with its performance and its cost. Salt brine had two responses also. Milton was not pleased with the performance of the suppressant. Blandford-Blenheim reported low cost and no environmental effects. Again, the lack in response could be due to proximity to the source. Salt brine is used mainly near the source.

No townships offered any comments on Bond-All or Coherex. All were unfamiliar with these products.

9.3 - Comparative Costs of Suppressants

Comparative costs were calculated based on contractor fees, application rates, equipment and maintenance costs and labor costs to the Townships. Costs were derived in dollars per kilometer per year for a 16-ft (4.9 m) width of road applied. The figures used were the actual costs to townships incurred during 1987 obtained from the respective townships involved in the study.

These costs do not account for extra savings or costs due to the use of the various suppressants. For example, Milton reports reduction of grading from twice a year to one grading per year. Yet additional costs are incurred due to the increased maintenance of potholes caused by road oiling. Coleman and Hallowell both report less grading and lower maintenance fees caused by the use of their respective dust suppressants.

The costs for Milton, NOTL, Coleman, Blandford-Blenheim and Armour were derived from the contractors' fees and the frequency of application during 1987. Hallowell was the only township that applied its own dust suppressant.

Costs for Hallowell were derived from equipment, labor, fuel and maintenance costs. Equipment and maintenance costs reflect the ratio of time the equipment was used for suppressant application. This ratio turned out to be approximately 28%. The costs do not account for management costs, various overhead costs or contractor profits. Also, the availability of the pulping liquor is dependent on proximity to the source. This builds in a variability to the cost comparison which is dependent on availability and shipping costs of the suppressant.

The figures are shown in Table 9.1. This table contains the applied cost of each suppressant, the application rate, the annual application rate, the comparative costs over a year and the normalized comparative costs.

The applied rate is the cost per litre to apply the suppressant. The application rate indicates the amount of suppressant used (liters) per kilometer of road over a 16-ft width. The yearly application rate is the amount of suppressant used (liters) per kilometer of road (16 ft wide) for one year. Comparative costs reflect the amounts spent by each township for 1 km of road (16 ft wide) for the year. The normalized comparative costs are the comparative costs normalized using a performance factor derived from the study. The comparative and normalized class transportation cost columns contain the respective figures from which the transportation cost has been eliminated.

The applied costs varied greatly ranging from $0.37/L for CaCl2 to $0.004/L for the Domtar pulping liquor. Application rates were the actual rates used by the township. These rates varied from 1614 L/km in NOTL to 9,942 L/km in Blandford-Blenheim. These rates are not comparable because there is no indication of performance built in. The yearly application rate gives a better comparison of amounts since this gives an indication of the performance based on the amount used in one season. Hallowell applied 99,500 L/km of pulping liquor for the year. This figure is approximately one order of magnitude higher than the next closest which is Blandford-Blenheim at 9,942 L/km. The lowest amount was $CaCl_2$ in NOTL.

The yearly application rate gives a partial indication of the performance of the suppressants. It is assumed that the yearly application rate is chosen partly on the basis of public complaints. This can vary greatly between townships and will affect the extent to which townships will attempt to control the dust problems. Using the application rate as the performance indicator, the ranking of

TABLE 9.1

COST COMPARISON OF DUST SUPPRESSANTS

		Unit Costs				Single Application Costs (16'width)				As Applied (16' width)					Normalized Costs	
Township	Suppressant	Applied Cost ($/L)	Distance Shipped (K)	Trans. Cost ($/L)	Less Trans. Cost ($/L)	Application Rate (L/K)	Trans. Costs ($/K)	Total Costs ($/K)	Less Trans. Costs ($/K)	Application Rate (L/K/year)	# of Appl. (/year)	Trans. Costs ($/K/year)	Total Costs ($/K/year)	Less Trans. Costs ($/K/year)	Total Costs ($/K/year)	Less Trans. Costs ($/K/year)
NOTL	Calcium Chloride	0.370	390	0.040	0.330	1614	65	605	540	3228	2	129	1,209	1,080	108	97
Milton	Industrial Oil	0.178	50	0.004	0.174	6610	26	1,181	1,155	6610	1	26	1,181	1,155	59	58
Hallowell	Pulping Liquor	0.004	45	0.004	0.001	4681	16	19	3	99500	Spotting	352	421	129	235	63
Armour	Crankcase Oil	0.165	83	0.007	0.159	5650	37	932	895	5650	1	37	932	895	9	9
Coleman	Tembind	0.067	100	0.010	0.058	2772	27	186	159	2772	1	27	186	159	100	86
Blandford-Blenheim	Salt Brine	0.019	0	0.000	0.019	9942	0	186	186	9942	1	0	186	186	186	186

suppressants would be Tembind, calcium chloride, crankcase oil, mixed industrial oils, salt brine and pulping liquor.

The comparative costs give one indication of the value the township received for using the particular suppressant. Again, these costs are assumed to reflect the cost for controlling dust based on public complaints. That is, these costs can be compared directly under the assumption that the road authorities are just applying sufficient suppressants to meet the public expectation of control. The ranking by value in this case is salt brine and Tembind, pulping liquor, crankcase oil, industrial oils, and calcium chloride.

Another more objective indication of value is found by a cost comparison weighing the costs using a performance indication ratio. As an adjustment, the ratio of dust at 1 m behind the moving vehicle (average of 8 runs) to the comparable salt brine figure (i.e. greatest dust) has been used. These results indicate relative costs according to the performance of the suppressants. Both crankcase and industrial oil have the best cost versus performance figures with values of $9 and $59 respectively. Tembind and CaCl2 were ranked next at $100 and $108. Salt brine followed at $186 and pulping liquor was last at $235. The pulping liquor results may be misleading since most of the suppressant application was spotting in front of houses. This could give it a lower performance rating and thereby bias it to appear more costly than it actually is. The performance indicators used are all relative to salt brine which had the worst performance during the study.

Finally, it is necessary to account for the effect of transportation costs in the overall costs. Because most of the suppressants are applied by contractors, these costs are subject to a large relative uncertainty.

To eliminate variability due to transportation expenses the costs have also been derived subcontracting the transportation costs from the total. An estimated transportation cost of $0.08/ton/km was calculated which for the most part reduced the total costs slightly. The ranking remained the same however, with the exception of pulping liquor for

which transportation costs represent the majority of expenses associated with the application. Approximately 73% of the total costs arise from the shipping to pulping liquor. This causes a major change in the relative ranking of pulping liquor causing it to move up to third from last. The overall ranking of suppressants when comparing the normalized total costs (less transport costs) is crankcase oil, industrial oils, pulping liquor, tembind, $CaCl_2$ and salt brine.

It must be emphasized that there is enough uncertainty in these figures that generalization to all roads-soil types, grading practices, etc. could be misleading. The adjustments based on the mobile sampler agree very well with visual rankings of the dust generation for the roads. However, the additional nuisance factor of oily dust and the "environmental" costs of the suppressants cannot be taken into account here.

10 - CONCLUSIONS AND RECOMMENDATIONS

10 - CONCLUSIONS AND RECOMMENDATIONS

At the beginning of this project it was recognized that there was some doubt as to whether the continued use of waste oils as dust suppressants would be permitted. These suspicions combined with the chemical testing now required for oil intended for this use, have led some oil suppliers to declare their intentions to discontinue dust suppression within the year. Certainly the banning of waste oils for this use in several U.S. states and some provinces has raised the level of concern as stated by the suppliers, users, and the Ministry. The results of this study illustrate the problems of used oils. One supplier furnished (after several requests) a sample of oil which was abnormally free of impurities and thus unlikely to be typical. Another willingly, and unknowingly supplied a sample containing almost 500 ppm of PCBs. In the latter case the supplier, upon receiving results from their testing laboratory, sealed the tank before distribution. The results of the first two independent tests that resulted in the oil originally being released for distribution were negated by later tests. Whether the original tests were in error, or the PCBs were bound to a separated sludge, or for whatever reason, the incident demonstrates the potential for things to simply go wrong. Oil is a highly variable waste and the results of this study show that diligent testing and monitoring are required if the end use results in release to the environment.

The performance of oil as a dust suppressant is excellent. Dust generation at both sites investigated was well controlled throughout the study. However, it should be noted that environmental perceptions go beyond the absolute levels of dust. It was suggested in earlier sections that the individual road authorities may have arrived at an application regime that balances control costs with the level of control expected by the affected residents. Within this reference frame, it may be hypothesized that the oiled roads need to be better controlled because the dust from the oiled roads is inherently more noxious, or is perceived to be more noxious, than the dust from other roads. The sampling teams also made comments during this project which

support the view that the other roads are perceived as "dusty" but the oiled roads were "dirty". The difference to the residents may be greater than that due to soiling potential and may be becoming greater as the general awareness of the population of trace level contaminant issues rises.

The spent pulping liquor in Hallowell is also a waste, and is recognized by the local residents to be a waste. However, those persons spoken with during the field studies were generally of the opinion that the substance was innocuous. This view, plus the fact that the liquor is free at the Trenton plant are key reasons for its use. The performance is relatively good, considering that it is a readily soluble substance on a porous soil. A good level of performance requires frequent application (several times weekly), and the cost-effectiveness would be very sensitive to changes in transportation costs.

Calcium chloride offers a level of control approaching that of oil but with a much reduced risk of environmental contamination and greater costs.

The choice of suppressant in any given area should include three main criteria - cost, effectiveness, and environmental impacts. Environment in this case includes some concern about the aesthetics as well as the potential contaminants.

The risks of adverse contamination from waste oil cannot be estimated from the small number of samples available here. An intensive survey of the quality of oil in all waste pathways would be required to make a full assessment. Such a survey would also yield valuable evidence on the value of voluntary self-monitoring. As a corollary, the sites studied here represent a tiny fraction of the treated roads in the province and it would be useful to prepare an assessment of the state of contamination of a more representative sample of Ontario's roads. Such a study might adopt a standard set of indicator parameters with samples to be obtained by local MOE personnel.

Where a high degree of dust control is required, it can be provided by calcium chloride or waste oil. The user must decide if the greater risks of contamination and associated problems are acceptable for the lower cost of the oil. It is recommended that MOE enforce testing procedures to minimize this risk but ensure that users are aware of the potential for significant and costly impacts. Other materials investigated in this study are likely to be attractive only locally because of their reduced effectiveness and higher sensitivity to transport costs. Environmental impacts are not likely to pose constraints for these substances. Local opportunities (nearby supply) and policies are what determines the choice of suppressants in current use.

The purposes of this study did not include a detailed survey of policies and practices throughout the province, but it did become apparent during the selection of the study sites that there was great variation throughout the province. This study has contributed to the information base and further research will help establish the guidelines and procedural assistance required to make the most cost-effective and environmentally compatible choices.

LIST OF REFERENCES

LIST OF REFERENCES

Aquin, R., P. Korgemagi, and D. F. Lynch. Evaluation of Tembind 35 Dust Palliative. Ontario Ministry of Transportation and Communications. MI-83. January, 1986.

B.C. Ministry of Environment. Personal Communication with Dave Douglas, Waste Management Branch, February 4, 1987.

Bell, J. O. Recycling of Used Lubricating Oil as a Dust Suppressant. PACE Report No. 76-7. December 1976.

Blackwood, T. R. and D. C. Drehmel, 1982. New Concepts for Control of Fugitive Particle Emissions from Unpaved Roads. Prepared by Monsanto Research Corporation and presented at Sumposium on the Transfer and Util. of Part. Control Technol., Denver, Colorado, July 1979: 333-336.

Bollen, W.B. Microbial Transformations and Effects of Dehydrated Ammonia - Base Sulphite Spent Liquor in Soils. TAPPI, Vol. 38(4): 208 - 214. April, 1955

Boyd, K. R. Evaluation of Calcium Lignosulfonate as a Dust Palliative. Report No. 1. Manitoba Dept. of Highways and Transportation. Materials and Research Division. December, 1980.

Boyd, K. R. Evaluation of Calcium Lignosulfonate as a Dust Palliative. Report No. 2. Manitoba Dept. of Highways and Transportation. Materials and Research Division. April, 1983.

Environmental Protection Agency. Personal Communication between B.C. Ministry of the Environment and Dr. A. D. McIntyre, Technical Services Group, EPA, 1980. (As quoted in Mason et al, 1981).

Environment Quebec. Personal Communication with Raymond Perrier, Director General of the Terrestrial Environment. February 3, 1987.

Freestone, F. J. Runoff of Oils from Rural Roads Treated to Suppress Dust. EPA-R2-72-054. Oct. 1972.

Ganin, G. I., V. T. Kaplin and V. A. Kriul'kov. MATERIALY. Vsesayuznogo Symposiuma Po Sovremennym Probleman Samoochisschcheniya i Regulirovaniya Kachestua Vody, 5th Vol. 3, p.13 - 17, 1975. (As quoted in Mason et al, 1981).

Gillham, R. W., J. F. Barker, R. S. Carter and A. S. Abdul. Application of Industrial Liquid Waste to Secondary Roads in Ontario for Dust Control: Implications with Respect to Groundwater Quality. Prepared by Dept. of Earth Sciences, University of Waterloo for Waste Management Branch, Ontario Ministry of the Environment, Toronto. July, 1985.

Langlois, P. and G. Dallaire. Etude de l'efficacite de differents produits d'abut-poussiere. Laboratoire Central, Ministere des Transports. Ste. Foy. Dec. 1979.

L. S. Love & Associates Canada Limited. Report on the Environmental Effects of Waste Oil as a Road Dust Suppressant (Phase 1). Prepared for Ontario Ministry of the Environment, Pollution Control Branch, Toronto. March 1978.

L. S. Love & Associates Canada Limited. Report on the Environmental Effects of Waste Oil as a Road Dust Suppressant (Phase II). Prepared for Ontario Ministry of the Environment, Pollution Control Board, Toronto. May, 1979.

Mackenzie & Fiemann Ltd. Personal Communication between B.C. Ministry of Environment and Company Representative in Vancouver. 1980. (As quoted in Mason et al, 1981).

Majors, W. Personal Communication with Acres International Limited. March 1988.

Mason, D. R., C. Harnadek and C. Zessler. Road Dust Abatement in British Columbia: Alternative to Used Lubricating Oil. Summary of Available Information. B.C. Ministry of Environment, Waste Management Branch, Victoria. January 1981.

McDougall, J. I. Field Trials of Lignosulfonate Dust Palliative. Ontario Ministry of Transportation and Communications. Downsview. June, 1986.

Metzler, S. C. and C, Jarvis. Effects of Waste Oil contamination. Environmental Progress, Vol. 4(1): 61 - 65. February, 1985.

Midwest Research Institute. Dust Control for Haul Roads. Prepared for Bureau of Mines, U.S. Dept. of the Interior. Washington, D.C. February 1981.

Motto, H. L. et al. Lead in Soils and Plants: Its Relationship to Traffic Volume and Proximity to Highways. Env. Sci. & Tech. Vol. 4:231-237, March, 1970. (As quoted in Freestone, 1972).

Mueller, Dr. J. C. Personal communication between B.C. Ministry of Environment and Associate Head, Division of Applied Biology, B.C. Research. 1980. (As quoted in Mason et al, 1981)

New Brunswick Department of Municipal Affairs and the Environment. Personal Communication with S. Godin, Pollution Control Branch. February 3, 1987.

Nolin, G. Etude de l'efficacite de differents produits d'abat-poussiere. Quebec Service de la Conservation des chanssees. 1980.

Norman, C. Lignosulfonates as a Dust Suppressant: An Environmental Assessment. Ontario Ministry of Transportation and Communications. August, 1984.

Nova Scotia Department of the Environment. Personal Communication with Duncan McKay, Environmental Engineer. February 5/87.

Ontario Ministry of the Environment. Ontario Detects Low Levels of PCBs in Road Oil. News Release February 23, 1978. (As quoted in Rudolph, 1980.)

Pulp and Paper Institute of Canada. Personal Communication between B.C. Ministry of Environment and S. Prahacs, Director, Environmental and Energy Research Division, PPIC. 1980. (As quoted in Mason et al, 1981).

Roald, S. O. The Effects of Sublethal Concentrations of Lignosulfonates on Growth, Intestinal Flora and Some Digestive Enzymes of Rainbow Trout. (Salmo gairdneri). Aquaculture Vol. 12: 327-335 1977a.

Roald, S. O. Acute Toxicity of Lignosulfonates on Rainbow Trout (Salmo gairdneri). Bull. Env. Contam. Toxicol. Vol. 17(6). 1977b.

Rudolph, M. S. Systems of Recovery and Reuse of Used Lubricating Oils: A State of the Art Study. Ontario Ministry of the Environment, 1978.

Rudolph, M. S. Road Oiling. An Example of Environmental Mismanagement. Alternative Vol. 9(2): 32 - 34. Spring, 1980.

Singer, R. D. et al. An Environmental Evaluation of Dust Suppressants: $CaCl_2$ and Lignosulfonate. A Mining Research Contract Report No. HOZ12027 Bureau of Mines. US Dept of Interior, Washington, DC. June, 1982.

Sirota, G. R. The Regulatory Implications of Waste Oil Analysis. Eighth Canadian Waste Management Conference, Halifax, N.S. pp. 221-226. Sept. 3 - 5, 1986.

Skinner, D. J. Preliminary Review of Used Lubricating Oils in Canada. Report No. EPS 3-WP-74-4. June, 1974 and Revised in January 1976.

Suns, K., C. Curry, D. Wilkens and C. Crawford. The Effects of Road Oiling on PCB Accumulation in Aquatic Life. Ontario Ministry of the Environment, Rexdale, Ontario. 1980.

Suprenant, N. F. and W. H. Battye (GCA Corp). Fate of Hazardous and Nonhazardous Wastes in Used Oil Disposal and Recycling. Bedford, Ma. October 1983.

Techman Engineering Ltd. Road Dust Suppression in Northern and Western Canada. Review of Alternatives and Existing Practices. Prepared for Environment Canada and the Governments of Alberta, B.C., Manitoba and the Northwest Territories, 1982a.

Techman Engineering Ltd. Road Dust Suppressant in Northern and Western Canada. Manual of Recommended Procedures. Prepared for Environment Canada and the Government of Alberta, BC, Manitoba and the Northwest Territories. 1982b.

UMA Engineering Limited. Guidelines for Cost Effective Use and Application of Dust Palliatives. Draft Report prepared for the Roads and Transportation Association of Canada, 1987.

Wagar, L. M. Personal Communication with Maintenance Programs Engineer, BC. Ministry of Transportation and Highways, Victoria. February 17, 1987.

Whisman, M. L., J. W. Goetzinger, and F. D. Cotton. Waste Lubricating Oil Research: A Comparison of Benchtest Properties of Re-refined and Virgin Lubricating Oils. U.S. Department of the Interior, Bureau of Mines, 1974. (As quoted by Gillham et al, 1985).

Wilson, R.C.H. J. Fish Res. Bld. Canada. 29, 1225, 1972 (As quoted in Roald, 1977b).

Wong, A. Characteristics of Spent Sulphite Lignor - A CPPA/TS Sulphite Committee Survey. Pulp and Paper Canada, Vol. 82(6): 74-81 1981.

Zitko, V. Personal communication between B.C. Ministry of Environment and Program Head, Fisheries & Environmental Research, Fisheries and Oceans Canada. 1980. (As quoted in Mason et al, 1981)

APPENDIX A

LIST OF CONTACTS

APPENDIX A

LIST OF CONTACTS

Provincial Agencies	Contact
Alberta Department of Environment Edmonton	Mr. Albert Poulette Air Quality Branch
Alberta Dept. of Transportation & Utilities Edmonton	Mr. Richard Orell Maintenance Services
Alberta Energy Resources Conservation Board Calgary	Mr. Roger Creasey Land Management
B.C. Ministry of Environment Victoria	Mr. Dave Douglas Waste Management Branch
B.C. Ministry of Transportation & Highways Victoria	Mr. Wagar Maintenance Services Branch
Manitoba Department of Environment & Workplace Safety and Health Winnipeg	Mr. Adrian Jackson Air Quality
Manitoba Department of Highways and Transportation Winnipeg	Mr. Ken Boyd Materials and Research Division
Newfoundland Department of Environment St. Johns	Mr. Carl Strong Industrial Engineering Division Pollution Control
Nova Scotia Department of the Environment Halifax	Mr. Duncan Mackay Environmental Engineer
Nova Scotia Department of Transportation Halifax	Mr. McDermid Director of Maintenance
New Brunswick Dept. of Municipal Affairs and the Environment Fredericton	Ms. Simone Godin Pollution Control Branch

Ontario Ministry of Transportation and Communications	Mr. F. Leech Environmental Quality Control
Quebec Environment Ste. Foy	Mr. Raymond Perrier Director General Terrestrial Environment
Quebec Ministry of Transports Quebec City	Mr. Jean-Real La Haye Director
Saskatchewan Department of the Environment Regina	Mr. R. E. Byers Manager Waste Management Section Land Protection Branch
Saskatchewan Dept. of Highways and Transportation Regina	Mr. Ken Lees Director Geotechnical and Materials Testing Branch

<u>Federal Agencies</u>

Environment Canada Environmental Protection Service Hull, Quebec	A. Hazra Å/Chief Transportation Systems Division
Environment Canada Environment Protection Service Regina, Saskatchewan	John Witteman Manager, Regional Office

<u>US Agencies</u>

Dept of Environmental Conservation Albany, New York	Frank Murphy Division of Solid and hazardous Wastes
Environmental Protection Agency Washington, DC	Hotline

<u>Associations</u>

Roads and Transportation Association of Canada Ottawa	Brian E. Hicks Senior Programs Manger

APPENDIX B

SASKATCHEWAN ENVIRONMENT GUIDELINES
FOR DUST SUPPRESSION

Saskatchewan Environment

Guidelines for the Use of Waste Petroleum Products for Dust Suppression

1. Application in areas with sensitive land use should be avoided (i.e., near recreational areas, specialty crops, etc.).

2. Application in areas with light textured soil should be avoided.

3. Application within 100 metres of surface water should be avoided.

4. Application within 50 metres of a private or community well should be avoided.

5. Application to areas where depth to ground water is less than 5 metres should be avoided.

6. Application rates should not exceed 1.0 litres per square metre.

7. If puddles form they should be filled with gravel or other suitable road material.

8. If application is carried out in an area where surface drainage enters a nearby water body or watercourse, and a rainfall event occurs within 5 days subsequent to application, water samples should be taken and analyzed for phenols.

9. Used motor oil should not be applied due to high concentrations of contaminants, including heavy metals.

DJC/mf

82/05/31

Saskatchewan Environment

Information Required for Consideration of a Proposed Dust Suppression Project

1. Site of proposed project (include LSD of start and end of roadway).

2. Ownership of roadway (public or otherwise).

3. Length of roadway.

4. Soil type (sand, silt, clay).

5. Average depth to ground water.

6. Land use adjacent to the roadway.

7. Does surface drainage from the site enter any water bodies (i.e., sloughs, ponds, lakes, dugouts)? If yes specify size, location and use.

8. Does surface drainage from the site enter any water courses (i.e., coulee, creek, stream, river)? If yes give names of water courses if available.

9. Are there any known water wells within 100 metres of the roadway? If yes specify LSD, distance from roadway and depth to ground water.

10. Type of dust suppressant to be used and supplier.

11. Estimated volume of suppressant to be applied.

12. Describe any precautions planned to prevent runoff of the suppressant onto adjacent land.

13. Have dust suppression projects been carried out in previous years at this site? Any complaints or problems encountered?

In all cases please provide a sketch of the area showing distances to ground water wells, surface water bodies, and the significant surface drainage network within 100 metres of the roadway (eg., coulees, ditches).

82/06/14

DJC/mf

APPENDIX C

DUST SUPPRESSION SELECTION AND PERFORMANCE CRITERIA

APPENDIX C1

PRODUCT SELECTION CHART, (UMA Engineering, 1987)

	TRAFFIC VOLUMES AVERAGE DAILY TRAFFIC			SUBGRADE TYPE [2]			SURFACE MATERIAL FINES CONTENT Passing 75 μm Sieve					CLIMATE			ENVIRONMENTAL IMPACTS [5]
	LIGHT < 100	MEDIUM 100 - 250	HEAVY > 250 [7]	CLAY	SILT	GRANULAR	< 5%	5-10%	10-20%	20-30%	> 30%	RAINY	NORMAL	Dry Spells > 20 DAYS < 40% RH	
$CaCl_2$ NATURAL BRINE	●	●	◒	●	◒	○	○	◒	●	◒	○ [3]	○ [1,3]	●	○	◒
$MgCl_2$	●	●	◒	●	◒	○	○	◒	●	◒	○ [3]	○ [1,3]	●	◒	◒
Ligno-sulfonates	●	◒	○ [6]	●	◒	○	○	◒	●	●	◒ [3]	◒ [1]	●	●	◒
Petroleum Products	◒	○	○ [6]	◒	◒	◒	○	◒	◒	○ [4]	○ [4]	○ [3]	◒	◒	◒

DUST PALLIATIVE PERFORMANCE:
- ● GOOD
- ◒ FAIR
- ○ POOR

Notes

1. May leach out in heavy rain.
2. Subgrade will mix with surface material and impact on the quantity of fines.
3. May become slippery in wet weather.
4. Difficult to coat all particles and prevent "dust pockets."
5. All products listed may have an adverse environmental impact if used improperly.
6. Hard surface crust promotes potholes and breakup under heavy traffic.
7. May require higher or more frequent application rates (especially with high truck volumes).

APPENDIX C2

PERFORMANCE LIMITATIONS OF COMMON DUST SUPPRESSANTS (UMA Engineering, 1987)

DUST Suppresent	CLIMATIC LIMITATIONS	SURFACE GRAVEL CONSIDERATIONS	COMMENTS
Deliquescent and Hydroscopic Chemicals			
Calcium Chloride Magnesium Chloride Natural Brines	Loses effectiveness in dry periods with low humidity. Leached from road in heavy rain.	Not recommended in surface courses with low fines. Recommended 10 - 20% fines.	Calcium chloride most popular product. Surface can be rebladed under moist conditions. May become slippery in wet weather with high fines content in surface gravels.
Organic Non-Bituminous Binders			
Calcium Lignosulfonate Sodium Lignosulfonate Ammonium Lignosulfonate	Long dry period with low humidity does not affect product. Leached from road in heavy rain if not sufficiently cured. Leaching reduced with length of curing and use.	Best performance with high surface fines (10 - 30%) and dense compact surface with no loose gravel.	Generally ineffective if surface course low in fines and loose gravel on surface. Difficult to maintain as hard surface, but can be done under adequate moisture conditions. May be advantageous to apply two applications. May become slippery in wet weather with high fines content in surface gravel.
Petroleum Based Products			
Bunker Oil Asphalt Primer Emulsified Asphalt	Generally effective regardless of climatic conditions. May pothole in wet weather.	Best performance noted with lower surface fines ocntent (5 - 10%)	Hardened crust makes road surface difficult to maintain and reblade. Potholing and surface ravelling requires maintenance. Hardening of surface varies with type of product.

APPENDIX C3

APPLICATION RATES AND FREQUENCY, (UMA Engineering, 1987)

	TRAFFIC VOLUME (ADT)											
	<100				100 - 250				>250			
	Rate L/m²		Dilution with H_2O	Applications Per Year	Rate L/m²		Dilution with H_2O	Applications Per Year	Rate L/m²		Dilution with H_2O	Applications Per Year
	Initial	Subseqeunt			Initial	Subsequent			Initial	Subsequent		
Calcium Chloride	1.0-1.2	0.3-9.6	(Assumes 35% Sol'n)	1	1.2-1.5	0.6-1.0	N/A (Assumes 35% Sol'n)	1	1.5-1.8	1.0-1.2	(Assumes 35% Sol'n)	1-2
Magnesium Chloride	1.5	0.8	30% Sol'n	1	1.5-2.0	1.0	N/A (Assumes 30% Sol'n)	1	2.0	1.25	30% Sol'n	1-2
Ligno-sulfonates	0.9-1.1	0.7-0.9	1:1	1	1.0-1.3	0.7-0.9	1:1	1	1.3-1.6	0.9-1.1	1:1	1-2

A.D.T. - Average Daily Traffic

APPENDIX D

WASTE OIL DATA

APPENDIX D1

INORGANIC CONSTITUENTS
OF WASTE OILS

Element	Concentration (mg/L) Used Automotive Oils[1,2] Range	No. of Samples	Used Industrial Oils[1] Range	No. of Samples	Waste Oils[3] Range	No. of Samples
Al	0.4 - 800	58	2 - 36	2		
Ba	9 - 2000	51	5 - 220	2	0.83 - 130	22
Be	<0.01 - 2.4	12	- -	-		
B	3 - 20	2	- -	-		
Cd	0.06 - 2.3	16	1 - 8	2	0.25 - 2.2	22
Ca	270 - 3 986	52	- -	-		
Cr	0.03 - 60	40	1 - 31	2	<0.5 - 90	22
Cu	5 - 348	57	3 - 1160	2		
Fe	40 - 2000	59	1 - 200	2	<5.0 - 2000	22
Pb	<10 - 21 700	59	0 - 1400	2	8.0 - 3900	22
Mg	8 - 1600	56	0 - 1000	2	11 - 430	22
Mn	1 - 60	38	1 - 124	2		
Mo	1.4 - 50	6	0 - 19	2		
Ni	0 - 50	46	0 - 27	2	0.18 - 8.3	22
P	500 - 2000	15	- -	-		
Se	<0.3 - <1	2	- -	-		
Si	8 - 530	45	1 - 63	2		
Ag	0.01 - <10	5	0 - 0.1	2		
Na	8 - 660	27	1 - 370	2		
Sr	0 - 30	3	- -	-		
SO_4	- -	-	- -	-		
S	3362 - 4325	10	- -	-		
Sn	0 - 112	16	1 40	2		
Ti	<0.1 - 30	4	0 - 7	2		
V	<0.07 - 140	27	0 - 25	2		
Zn	<10 - 3 000	1055	6 - 1100	2	<0.5 - 1200	22

[1]Gillham et al (1985) summarized data from the following sources
Whisman et al., 1974, Rudolph, M.J. 1978
Skinner, D.J., 1974, Can Am Oil Services
Bell, J.D., 1976, Franklin Associates

[2]Includes data from Suprenant et al, 1983

[3]Love & Associates 1979.

APPENDIX D2

SUMMARY OF ORGANIC ANALYSES OF WASTE OIL (Concentrations in mg/L)

Organic Compound	Formula	Gillham et al (1985)[1] Range	Surprenant et al (1983) Range	Rudolph (1978) Range
Normal and Branched Alkanes (27:)				
a-Pentane	C_5H_{12}	54 - 660		
n-Hexane	C_5H_{14}	170 - 1800		
n-Heptane	C_7H_{16}	210 - 1300		
iso-Hexane	C_6H_{14}	170 - 1800		
iso-Heptane	C_7H_{16}	210 - 1300		
Cyclic Alkanes (50%)				
Cyclohexane	C_6H_{12}	170 - 1800		
Cycloneptane	C_7H_{14}	210 - 1300		
Monoaromatic Hydrocarbons (13%)				
Benzene	C_6H_6	46 - 280	0.018 - 0.89	
Toluene	C_7H_8	23 - 2200	0.120 - 5.80	
Xylenes	C_8H_{10}	36 - 570		
Ethyl Benzene	C_8H_{10}	14 - 35		
Propyl Benzene	C_9H1_2			
1-methyl 3-ethyl benzene	C_9H_{12}	110 - 2500		
1-methyl propyl benzene	$C_{10}H_{14}$	500 est		
Polycyclic Aromatic Hydrocarbons (PAHs)				
naphthalene	$C_{10}H_8$	110 - 790		
2-methyl naphthalene	$C_{11}H_{11}$	200 est		
anthracene	$C_{14}H_{10}$	225 - 595		
Phenanthene	$C_{14}H_{10}$	225 - 595		
Pyrene	$C_{10}H_{10}$	450 - 1240	1.670 - 30.0_0	
Benzo(a) anthracene	$C_{20}H_{12}$	<5 - 660	0.870 - 30.00	
Benzo(a) pyrene	$C_{20}H_{12}$	<1 - 630	0.360 - 62.00	
Diphenylmethane	$C_{13}H_{12}$	630 est		
Heterocyclic Hydrocarbons (4%) and O-Containing Hydrocarbons				
Benzothiophene	C_8H_6S	2700		
Dibenzothiophene	$C_{12}H_8S$	13500		

Table D2
Summary of Organic Analyses of Waste Oil - 2
(Concentrations in mg/L)

Organic Compound	Formula	Gillhametal (1985) Range	Surprenant et al (1983) Range	Rudolph (1978) Range
Halogenated Hydrocarbons				
Dichlorodifluoromethane	CCl_2F_2	<1 - 500		
Trichlorofluoromethane	CCl_3F	<1 - 970		
1,1,1-Trichloroethane	$C_2H_3Cl_3$	<1 - 4100		
1,1,2-Trichloroethane	$C_2H_3Cl_3$	<1 - 4100		
Trichlorotrifluoroethane	$C_2Cl_3F_3$	<1 - 33		
1,1-Dichloroethylene	$C_2H_2Cl_2$			
1,2-Dichloroethylene	$C_2H_2Cl_2$			
Trichloroethylene	$C_2H\ Cl_3$	<1 - 650	0.180 - 2.60	
Tetrachloroethylene	C_2Cl_4	0 - 280	0.003 - 1.30	
PCBs			<1 - 9.7	<5 - 1135

[1]Based on MOE analyses.

APPENDIX D3

TOTAL PCBs IN OIL MIXTURES AS DETERMINED BY STANDARD AND MODIFIED ANALYTICAL METHODOLOGIES (SIROTA, 1986)

Sample	PCB Concentration (ppm)	
	Standard Method	Modified Method[1]
A	19	31
B	11	20
C	23	45
D[2]	22	34
E	5	8
F[2]	17	25
G	17	22
H	<1	2
I	<1	5
J	42	57
K	44	63

[1]Modified cleanup using fuming sulphuric acid.

[2]These samples were initially submitted for analysis as pure transformer oils and analyzed using standard methodology. The results were 34 and 25 ppm respectively. They were subsequently contaminated with diesel fuel and yielded the lower value as indicated in the above table. Following discussion of the results with the client, the samples were re-analyzed using the modified cleanup protocol, and yielded the original values.

APPENDIX D4

TEMPORAL CHANGES IN CONCENTRATIONS
OF TOTAL PCBs IN AN UNDISTURBED WASTE
OIL OF HIGH SOLIDS CONTENT[1] (SIROTA, 1986)

Sample Time Period	Total PCBs (ppm)
Initial	605
+ 1 day	580
+ 7 days	425
+ 28 days	118
+ 42 days	102

[1]The sample was mechanically mixed prior to taking the initial sample and was allowed to stand undisturbed while subsequent samples were taken over a 6-week period.

APPENDIX E

CALCIUM CHLORIDE AND LIGNOSULFONATE PERFORMANCE SUMMARIES

Performance Summary For Village Of Gretna Streets (Manitoba) (Boyd, 1983)

OBSERVATION PERIOD	WEATHER\ SUMMARY	SURFACE TYPE	MAINTENANCE REQUIREMENTS	DUST COLLECTOR DATA ($G/M^2/DAY$)	SURFACE CONDITION STATEMENT	DUST CONTROL RATING*	PERFORMANCE STATEMENT
June 18 to Aug. 4	Wetter than normal with near normal temperatures. (126.9 mm rainfall)	$CaCl_2$	Nil	1.4	Tight and fairly smooth. No potholing. Some loose coarse material evident at end of period.	4.0	$CaCl_2$ performed better during this wetter than normal period. Ca-lignosulfonate appeared to "wash out" more, forming residue pools at shoulder edges.
		Ca-ligno-sulfonate	Nil	0.7	Fairly tight, smooth, and no potholing. More loose coarse material evident than on $CaCl_2$ sections.	2.5	
Aug. 5 to Sept. 16	Normal precip. (43.9 mm) with slightly below normal temperatures.	$CaCl_2$	Nil	0.7	Tight and smooth. No potholing. Some loose aggregate visible.	5.0	Both sections performed well, but $CaCl_2$ was rated better due to no dust visible.
		Ca-ligno-sulfonate	Nil	0.9	Tightness fair; smooth with no potholing. Loose coarse aggregate visible.	3.0	
Sept. 17 to Oct. 27	Wetter than normal with normal to slightly cooler temperatures (135.2 mm rainfall)	$CaCl_2$	Tight bladed on Oct. 21 for winter preparation.	0.4	V. Little ravelling; no potholing. Ride is good. Loose coarse material visible.	4.0	Both sections rated as good. $CaCl_2$ rated as slightly better because of less ravelling, better ride, and higher dust control rating.
		Ca-ligno-sulfonate	Tight bladed on Oct. 21 for winter preparation.	0.6	Roughness reported prior to blading. No potholing. Loose coarse material visible. Some dust.	3.0	

Performance Summary Statement: The $CaCl_2$ performed better than Ca-lignosulfonate; particularly during the wet weather periods. Both types performed satisfactorily, however, according to the observations of both highways and village council personnel.

* See Dust Control Rating Criteria at end of table

PERFORMANCE SUMMARY FOR TOWN OF WINKLER (Manitoba) (Boyd, 1983)

OBSERVATION PERIOD	WEATHER SUMMARY	SURFACE TYPE	MAINTENANCE REQUIREMENTS	* DUST COLLECTOR DATE ($G/M^2/DAY$)	SURFACE CONDITION STATEMENT	DUST CONTROL RATING	PERFORMANCE STATEMENT
June 11 to Aug. 4	Wetter than normal with near normal temperature. Two heavy rainfalls of 125 mm and 75 mm occurred (203.4 mm rainfall)	$CaCl_2$	Nil	0.3	Tight and smooth, no potholing and no loose aggregate. Ride good.	4.0	$CaCl_2$ performed considerably better. Ca-lignosulfonate washed out by heavy rains the day of application and deteriorated rapidly under heavy traffic.
		Ca-lignosulfonate	Watered, bladed and rolled once on Pembina Ave. E. only. 2nd application of 0.2 gal/yd.^{2}	0.4	Tightness fair-good, with limited potholing. Loose aggregate evident on all sections.	2.2	
Aug. 5 to Sept. 15	Normal precip. with slightly below normal temperatures (50.8 mm rainfall)	$CaCl_2$	Nil	0.2	Fairly tight and smooth. No potholing. Same loose aggregate. Good appearance. Ride good.	3.0	$CaCl_2$ again performed significantly better and rated as good. Ca-lignosulfonate section ratings vary from fair to poor.
		Ca-lignosulfonate	Watered, bladed and rolled twice on Pembina Ave. E. 3rd application at 0.4 gal./yd.^{2}	0.5	Very rough, major potholing, and very dusty prior to 3rd application. Balance of streets fair to poor.	1.5	
Sept. 16 to Oct. 27	Wetter than normal with near normal temperatures. (156.8 mm rainfall)	$CaCl_2$	Tight bladed once.	0.1	Fairly tight and smooth. Limited potholing and ravelling. Some loose aggregate. Ride and appearance good.	3.0	$CaCl_2$ performed considerably better and was rated as good. Ca-lignosulfonate sections deteriorated more quickly with wetter weather and heavier traffic and were rated as fair.
		Ca-lignosulfonate	Tight bladed and rolled once.	0.4	Very rough, some washboard limited potholing. Fairly dusty.	2.0	

Performance Summary Statement: $CaCl_2$ outperformed Ca-lignosulfonate during entire testing period, especially during wetter weather. The performance of the Ca-lignosulfonate sections were hampered by the combination of heavy rainfalls and heavier traffic than the $CaCl_2$ sections.

PERFORMANCE SUMMARY FOR TOWN OF MORDEN, Manitoba (Boyd, 1983)

OBSERVATION PERIOD	WEATHER SUMMARY	SURFACE TYPE	MAINTENANCE REQUIREMENTS	DUST COLLECTOR DATA ($G/M^2/DAY$)	SURFACE CONDITION STATEMENT	DUST CONTROL RATING	PERFORMANCE STATEMENT
June 29 to Aug. 3	Wetter than normal with near normal temperatures. (101.4 mm rainfall)	Ca-ligno-sulfonate	Nil	0.3	Tight surface, smooth with some loose fines. Ride and general appearance good. Low dust except for Railway Ave. where visibility was restricted.	3.0	Performance rated as good with satisfactory dust control.
Aug. 4 to Sept. 15	Normal precip. with slightly below normal temperature (50.8 mm rainfall)	Ca-ligno-sulfonate	Nil	0.2	Fairly tight, smooth, some loose fines. Ride is good. Thin dust layer present.	3.0	Entire test section performed well and are rated as good.
Sept. 16 to Oct. 27	Wetter than normal with near normal temperatures (156.8 mm rainfall)	Ca-ligno-sulfonate	Tight bladed once.	No dust collection	Fairly tight, smooth, some loose fines. Ride and appearance good. Thin dust layer observed.	3.0	Performance is good. Ca-lignosulfonate still evident.

Performance Summary Statement: The performance of Ca-lignosulfonate was rated as good for entire inspection period. Initial deterioration was noted at first due to heavy rainfall; the sections remained similar for remainder of testing period. The Town of Morden found Ca-lignosulfonate to be effective as "it lasted much longer than $CaCl_2$ and required less grading and almost no watering".

Performance Summary For Village Of St. Claude, Manitoba (Boyd, 1983)

OBSERVATION PERIOD	WEATHER SUMMARY	SURFACE TYPE	MAINTENANCE REQUIREMENTS	DUST COLLECTOR DATA ($G/M^2/DAY$)	SURFACE CONDITION STATEMENT	DUST CONTROL RATING	PERFORMANCE STATEMENT
June 15 to Aug. 5	Wetter than normal with near normal temperature (126.2 mm rainfall)	Ca-ligno-sulfonate	Nil	0.2	Tightness fair, smooth, limited potholing. Loose fine aggregate evident. Ride is good. Ca-lig. pooled at shoulder edges during heavy rainfalls.	2.5	Performance was rated as fair-good. Ca-lignosulfonate is deteriorating rapidly with wet weather.
Aug. 6 to Sept. 14	Normal precip. with slightly below normal temperatures (31.7 mm rainfall)	Ca-ligno-sulfonate	Tight bladed once, no water.	0.3	Very rough, major pot-holing, ravelling and washboard prior to being bladed. Loose material. Ride is fair. Very dusty.	1.2	Performance was rated as fair-poor. Product lacked cohesion after being bladed. (should have been watered and rolled when bladed).
Sept. 15 to Oct. 26	Wetter than normal with near normal temperatures (109.3 mm rainfall)	Ca-ligno-sulfonate	Tight bladed once, no water.	—	Rough with potholes prior to blading. After blading surface remained tight and smooth with less washboard and potholing. Ride improved.	3.5	Improvement over previous periods due to combination of more rainfall and the previous years $CaCl_2$ treatment coming to the surface.

Performance Summary Statement: The use of Ca-lignosulfonate was not successful and the overall performance of the product rated as fair to poor. The reasons are thought to be above average rainfalls washing out the product combined with the sandy subgrade in the village streets. Whether $CaCl_2$ would have worked better was not determined, but the village feels $CaCl_2$ is a more dependable product in their area.

PERFORMANCE SUMMARY FOR TEST SITE I : P.R. 334

(Manitoba) (Boyd, 1980)

Observation Period	Weather Summary	Surface Type	Maintenance Requirements	Dust Collector Data ($g/m^2/day$)	Surface Condition Statement	Dust Control Rating	Performance Statement
June 24 to July 31	Much drier than normal with near normal temperatures.	$CaCl_2$	watered 3 times	0.7	Tight and fairly smooth. Few small pot-holes. Some loose fines evident near end of period.	3.5	Ca-lignosulfonate section performed significantly better during this dry period.
		Ca-lignosulfonate	none	0.3	Tight and fairly smooth Few small potholes. Better appearance than $CaCl_2$ section.	4.7	
Aug. 1 to Sept. 30	Wetter and slightly cooler than normal.	$CaCl_2$	watered and tight bladed 2 times	0.6	Surface condition romained good with the aid of mentioned maintenance.	4.3	Both sections performed almost equally. The Ca-lignosulfonate deteriorated slightly from previous period because of wet weather.
		Ca-lignosulfonate	watered and tight bladed 2 times	0.6	Surface condition remained good with the aid of mentioned maintenance.	4.8	
Oct. 1 to Oct. 31	Normal precipitation with slightly below temperatures.	$CaCl_2$	none reported	0.5	Loose fine material observed at the beginning and coarse sizes ravelling at the end.	3.4	Both sections performed similarly until near the end of the period when the $CaCl_2$ surface appeared to have greater deterioration.
		Ca-lignosulfonate	none reported	0.8	Loose fine material at beginning but appeared tighter than $CaCl_2$ at end of period	3.5	

Summary Performance Statement: The Ca-lignosulfonate performed better than $CaCl_2$; particularily during the dry weather at the beginning of the trial period.

PERFORMANCE SUMMARY FOR TEST SITE II : P.R. 405 (Manitoba) (Boyd, 1980)

Observation Period	Weather Summary	Surface Type	Maintenance Requirements	Dust Collector Data ($g/m^2/day$)	Surface Condition Statement	Dust Control Rating	Performance Statement
June 24 to July 31	Significantly drier than normal with near normal temperatures	$CaCl_2$	watered 2 times	2.1	Surface remained fairly tight with patches of loose material observed. A few potholes.	4.3	Both sections performed similarly, but the Ca-lignosulfonate was rated slightly better due to lower dust collection.
		Ca-lignosulfonate	none	0.6	Surface remained tight with small amount of loose coarse material observed at beginning. A few potholes	4.3	
Aug. 1 to Sept. 30	Wetter and slightly cooler than normal	$CaCl_2$	Watered and tight bladed once	2.2	Rideability and surface deteriorating, loose material. Potholing more frequent	4.1	Ca-lignosulfonate and $CaCl_2$ performed similarly with the exception of dust collection.
		Ca-lignosulfonate	watered and tight bladed once	1.0	Rideability and surface deteriorating. Tighter than $CaCl_2$. Potholing more frequent.	4.0	
Oct. 1 to Oct. 31	Slightly wetter and cooler than normal	$CaCl_2$	tight bladed once	2.3	Very rough, major potholing, much loose material on surface	3.3	The Ca-lignosulfonate performed marginally better in that its surface was tighter and less dust collected than on $CaCl_2$ section.
		Ca-lignosulfonate	tight bladed once	1.1	Surface fairly tight, major potholing to lesser degree than $CaCl_2$	4.0	

Summary Performance Statement: The performance of the Ca-lignosulfonate was rated marginally more effective than the $CaCl_2$ based on maintenance requirements and the results of the dust collector data.

PERFORMANCE SUMMARY FOR TEST SITE III : CONTROL STRUCTURE ROAD (Manitoba) (Boyd, 1980)

Observation Period	Weather Summary	Surface Type	Maintenance Requirements	Dust Collector Data ($g/m^2/day$)	Surface Condition Statement	Dust Control Rating	Performance Statement
June 24 to July 31	Significantly drier than normal. Near normal temp.	$CaCl_2$	watered 2 times	1.3	Surface fairly tight. Few small potholes	3.8	Both sections performed similarly.
		Ca-lignosulfonate	none	0.9	Surface fairly tight. Few small potholes	3.6	
Aug. 1 to Sept. 30	Wetter and slightly cooler than normal	$CaCl_2$	Each section was maintained as follows: Tight bladed once in Aug. and once in late Sept. On Sept. 2 both were totally re-laid and treated with Ca-lignosulfonate	2.3	Surface deteriorated thru Aug,; washboard surface and large potholes forming.	3.9	Both sections deteriorated during wet weather and the performance was rated as poor.
		Ca-lignosulfonate		1.4	Remained good past mid-August, but by end of Aug. was in as poor condition as $CaCl_2$.	3.7	
Oct. 1 to Oct. 31	Slightly wetter and cooler than normal.	$CaCl_2$	none reported	1.5	Surface in fairly good condition. A few potholes. Surface tighter than other section at end of Oct.	3.8	The $CaCl_2$ with second treatment of Ca-lignosulfonate performed marginally better than the double treated Ca-lignosulfonate.
		Ca-lignosulfonate	none reported	1.6	A few potholes at beginning, but deteriorated at end of Oct. Many potholes and loose material on surface.	3.3	

Summary Performance Statement: The performances of either section was only fair during the dry period and poor during wet weather; neither was more effective than the other.

DUST CONTROL RATING (Boyd, 1980)

Rating	Condition
5	Dust free, no dust rises from passing vehicles
4	Thin dust, rises a few feet high when vehicle passes
3	Thin dust cloud, rises well above passing vehicles, vision not restricted
2	Thin-thick dust cloud, visibility fair - poor, dust drifting from roadway
1	Thick dust cloud, causes driver uncertainty when following, heavy dust drifting
0	Extreme dust conditions, takes 1 - 5 seconds for visibility to improve, visibility greatly restricted

Lignosulfonate (Tembind 35) Performance Tests by MTC on Roads in Ontario (McDougall, 1986)

LOCATION	DATE OF APPLICATION	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION	DATE OF APPLICATION	TYPE OF MATERIAL	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION
Twp. of Casey Lot 4-6 Con V	84 06 13	3.96	Good	Light	6	84 06 13 Lot 1-6 Con III, IV, & V	CaC_2	0.83	Fair	Light	5
Town of Bracebridge	84 06 13	1.49	Fair-Poor	Light	1						
Stephen's Bay Road	84 07 18	1.34	Fair		1						
Spence Twp. Ahmic Lake Rd.											
Method A *	84 06 20	3.72	Poor	Moderate	?	84 06 20 Spence Twp.	Road Oil	1.24	Good	Light	?
Method B *	84 06 20	3.72	Fair-Poor	Light	?						
Method C *	84 06 20	3.72	Fair Poor	Light	?						
Method D *	84 06 20	3.72	Poor	Moderate	?						
Twp. Georgian Bay, District Rd. 33											
Method B	84 06 21&22	5.73	Good	Nil-Light	-						
Method C	84 06 21&22	5.87	Good	Light	-						
Method D	84 06 21&22	4.18	Fair-Good	Moderate	-						

*See description of application methods at end of table.

LOCATION	DATE OF APPLICATION	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION	DATE OF APPLICATION	TYPE OF MATERIAL	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION
Parry Island Indian Reserve Wasausink Rd.											
Method B	84 07 03	5.32	Poor	Heavy	Had to Oil	84 07 03	Road Oil	1.74	Good	Light	?
Method B&D	84 07 03	5.32	Poor	Heavy	the Road						
South Sequin Estates Rd.											
Method B	84 07 04	4.77	Poor	Moderate	3	84 07 04	Road Oil	1.24	Good	Light	1
Town of Milton	84 05 17	1.58	Fair	Moderate	2[1]	84 05 17	Waste Oil	1.41	Good	Light[4]	0
Town of Milton	84 09 14	1.79	Fair	Moderate	2[1]	-	-	-	-	-	-
Town of Thornbury	84 06 04	0.76[1]	Good	Light	0	84 05 24[1]	Waste Oil	1.09[1]	Good	Light	0
Town of Thornbury	84 07 31	0.76[1]	Good	Moderate	0	-	-	-	-	-	-
St. Lawrence Seaway (St. Catherines)	84 06 04	3.75[1]	Good	Light	0	-	-	-	-	-	-
Township of West Lincoln	84 06 05	2.23	Fair	Moderate	2	84 05 31[1]	Calcium Chloride	3.38[5]	Fair	Moderate	2[1]
Walpole Island	84 06 06	2.45[1]	Fair	Moderate	-	-	-	-	-	-	-

LOCATION	DATE OF APPLICATION	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION	DATE OF APPLICATION	TYPE OF MATERIAL	APPLICATION RATE L/m²	DUST CONTROL RATING	DEGREE OF POTHOLING	NO. TIMES GRADED AFTER APPLICATION
Town of St. Mary's Concession 19	84 06 12	1.90[2]	Good	Light	0	84 06 05[1]	Calcium Chloride	3.38[5]	Good	Light	0
Town of St. Mary's Various Streets	84 06 12	1.09[1,2]	Fair	Light	0	-	-	-	-	-	-
Town of Bracebridge Robert Dollar Dr.	84 06 13	1.85[3]	Fair	Heavy	0	-	-	-	-	-	-
Township of Pittsburg	84 06 14	2.34	Good	Light	0	-	-	-	-	-	-
Township of Tiny	84 06 14	2.83	Good	Light	3	84 06 07	Waste Oil	1.36[1]	Good	Light	3
Township of Tecumseh	84 06 22	2.23	Good	Moderate	3	84 06 05[1]	Waste Oil	1.79[1]	Good	Moderate	3
Township of Palmerston North and South Canonto	84 06 26	-	Fair	Moderate	1	-	-	-	-	-	-

NOTES

1. Estimated
2. Original Application Rate. A second Light Application (0.82 L/m² +/-) was placed 2 weeks later.
3. Graded to a depth of 4 on before application of Tembind.
4. Small breaks in the stabilized oil surface were spray patched with asphalt emulsion and aggregate.
5. Tonnes of liquid calcium chloride per km.

APPLICATION METHOD A

RECOMMENDED METHODS OF APPLICATION USING 35% SOLIDS

1. Grade the road surface 7.6 cm (3 in.) deep to get rid of all the corrugations, pot holes and to loosen the road surface material to the depth penetration desired.

2. Grade the road 5.0 cm (2.0 in.) deep in a manner to leave a windrow on both sides. The distance between the windrows should be 5.5 m (18 ft).

3. Spray the road surface between the windrows.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

4. Using approximately half of the material in the windrows, cover the freshly sprayed dust control product.

5. Spray the road surface between the windrows.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

6. Blade the remainder of the material in the windrow evenly over the freshly applied dust control product.

7. It is important that the finished grade should be left with a crown 4.2 cm per m (1/2 in. per ft.) from the centreline to the edge of the road.

8. Spray the dust control product on the finished grade 6.7 m wide (22 ft.).

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

APPLICATION METHOD B

RECOMMENDED METHODS OF APPLICATION USING 35% SOLIDS

1. Grade the road surface 7.6 cm (3 in.) deep to get rid of all the corrugations, pot holes and to loosen the road surface material to the depth penetration desired.

2. Grade the road .1 m (20.0 ft.) wide.

3. Spray the road surface between the windrows.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate __ l/m^2 (__ gal./sq. yd.)

4. Grade the road surface 5.0 cm (2.0 in.) deep from the right side to the left side and back to the right side, in the same manner as mixing mulch. It might be necessary to make an extra pass with the grader to mix and level the material properly.

5. Spray the road surface again 6.1 m (20.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate __ l/m^2 (__ gal./sq. yd.)

6. Grade the road surface 5.0 cm (2.0 in.) deep from the left to the right side and back to the left side, in the same manner as mixing mulch. Again it might be necessary to make an extra pass with the grade to mix and level the material properly.

7. The finished grade should be left with a crown of 4.2 cm per m (1/2 in. per ft.) from the centreline to the edge of the road.

8. Spray the dust control product on the finished grade 6.7 m (22 ft.).

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate __ l/m^2 (__ gal./sq. yd.)

APPLICATION METHOD C

RECOMMENDED METHODS OF APPLICATION USING 35% SOLIDS

1. Grade the road surface 7.6 cm (3 in.) deep to get rid of all the corrugations, pot holes and to loosen the road surface material to the depth penetration desired.

2. Spray the road surface 6.1 m (20.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

3. Allow the dust control product to penetrate into the road surface.

4. Spray the road surface 6.1 m (20.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__gal./sq. yd.)

5. Allow the dust control product to penetrate into the road surface.

6. Grade the road surface approximately 2.5 cm (1.5 in.) deep leaving the finished grade with a crown of 4.2 cm per m (1/2 in. per ft.) from the centreline to the edge of the road.

7. Spray the dust control product on the finished grade 6.7 m (22.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

APPLICATION METHOD D

RECOMMENDED METHODS OF APPLICATION USING 35% SOLIDS

1. Grade the road surface 5.0 cm (2.0 in.) deep to get rid of all the corrugations, pot holes and to loosen the road surface material to depth penetration is desired, leaving a crown of 4.2 cm per m (1/2 in. per ft.) from the centreline to the edge of the road.

2. Spray the road surface 6.1 m (20.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

3. Allow dust control product to penetrate into the road surface.

4. Spray the road surface 6.1 m (20.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

5. Again allow the dust control product to penetrate into the road surface.

6. Spray the road surface 6.7 m (22.0 ft.) wide.

   Recommended Application rate .91 l/m^2 (.2 gal./sq. yd.)
   Actual Application rate ___ l/m^2 (__ gal./sq. yd.)

APPENDIX F

SULFITE LIQUORS/LIGNOSULFONATES
(CHEMISTRY AND ENVIRONMENTAL DATA)

Appendix F1 Organic constituents of sulphite liquor.(Gillham et al, 1985)

COMPOSITION

Water		87.5%
Suspended Solids (Fine fragments of Wood & Bark)		1.2%
Dissolved Solids:		
Sodium Carbonate	0.6%	
Sodium Bicarbonate	2.1%	
Lignin	1.8%	
Sodium Acetate	3.8%	
Sugars: Rhaminose, Arabinose, Xylose, Galactose, Glucose, Mannose	1.6%	11.3%
Unidentified High Molecular Weight Organic Compounds (by difference)	1.4%	

Lignin Degradation Products	ppm
phenol	<1
guaicol	2
syringol	29
vanillin	13
vanillic acid	2
syringaldehyde	4
3, 5-dimethoxy-4-hydroxypropiophenone	1
FATTY ACIDS	
myristic	6
palmitic	7
oleic	46
stearic	5
arachidic	19
behemic	9
lignoceric	4
3 unidentified	17
RESIN ACIDS	
2 unidentified	5
OTHERS	
Terbutol (2,6-di-t-butyl-4 methylphenyl-N-methyl carbamate)	<1

Appendix F2

CHEMICAL ANALYSIS OF TEMBIND A 003 (Norman, 1984)

Tembind A 003 is a mixed sodium ammonium base lignosulphonate produced from ammonium spent sulfite liquor.

This lignosulphonate product is available as sludge free, clean liquid and in powder form.

Physical Properties	Liquid	Powder
Viscosity (at 25 C), (centipoise)	200	—
pH of 25% solution*	5.0	4.5
Solids, (%)	48	95
Density, (g/cm^3 at 25 C)	1.23	0.53 bulk
Freezing point, (C)	-5	—
Solubility in water, (g/L)	Infinitely soluble	600

Chemical Properties	Liquid	Powder
Lignin content, (%) **	65	65
Reducing bodies, (%)	17	17
H.P.L.C. sugars, (%) ***	12	12
Methoxyl, (%)	7.1	7.1
Nitrogen, (%)	3	2.6
Sulphur, (%)	6	5.5
Sodium, (%)	3	3
Calcium, (%)	0	0
Fe, (ppm)	20	20
Ash, (%)	8	8

* Can be adjusted upon request.
** Estimated by uv spectrometric method
*** High pressure liquid chromatography method

- provided by Dr. A. Bialski, Technical Director
Temfibre Inc. May 1984

Appendix F3

CHEMICAL ANALYSIS OF
M & F CALCIUM LIGNOSULPHONATE (Norman, 1984)

% Solids (18 hours at 105 C)	45.4
Spec. gravity at 25 C	ND
pH	2.25
% Insol, residue (in 1:1 HCl)	trace
% Iron and Aluminum oxide ($Fe_2O+Al_2O_3$)	trace
% Calcium (CaO)	5.33
% Magnesium (MgO)	0.24
% Sulphate (SO_4'')	13.50
% Nitrate (NO_3')	nil
% Sodium (Na_2O)	trace
% Chloride (Cl')	trace
% Methoxyl	8.72
% Lignin	68.1
% Ligno-sulphonic acid	78.6
% Ca-ligno-sulphonate	84.1
% Reducing bodies	c. 25.2

Note:
Except for the solids content, specific gravity and pH value, all the above values are expressed in terms of mass of solids.

-provided by R.A. Sterk, Head, Chemicals Section, MTC Downsview, 1980.

Appendix F4

CHEMICAL ANALYSIS OF EDC SODIUM LIGNOSULPHONATE (Norman, 1984)

EDC Sodium Lignosulphonate is derived from high yield sodium bisulphite pulping of northern softwoods. EDC is available in liquid form at 55 - 60% DS concentration. Also available in 25% solids solution.

Typical Analysis of EDC

	g/kg Dry Solids
Na	78.7
S	94.0
SO_4 = as S	3.7
SO_3 = as S	62.4
S_2O_3 = as S	0.9
S = as S	nil
Total Inorganics	250.8
pH	5.0 - 6.0
UV Lignin	331.5
Total Carbohydrates	187.8
Reducing Sugars	50.4

- provided by Environmental Dust Control Ltd.
St. Vital, Manitoba 1984

Excerpted from 1963 California Water Quality Criteria Manual

SULFITE WASTE LIQUORS

1. General. The waste water resulting from the pulping of wood with calcium on magnesium bisulfite liquor with steam under pressure are known as sulfite waste liquors (SWL) or spent sulfite liquors (SSL). They contain in dissolved or very finely divided suspension approximately half of the weight of the wood used for pulping, and comprise fiber-binding substances such as lignin and pectin, hemicelluloses, sulfur dioxide, sulfites, polythionates, organic acids, calcium or magnesium, and numerous other organic and inorganic substances. Acid in reaction, they are high in BOD and dissolved organic matter, with a persistent pungent odor and a tendency to ~~foam in~~ receiving streams.

Gunter and McKee (2415) have summarized the chemical and physical characteristics of SWL. They point out that most SWL contains 10 to 14 percent total solids, with 5-day BOD values of about 30,000 mg/l. The lignin component of SWL comprises a great variety of high-molecular-weight compounds that include benzene or phenol complexes to which sulfonate has been added for pulping purposes. SWL can be detected in dilute concentrations in receiving waters by the Pearl-Benson test, which is precise and reproducible but not specific. Many natural phenolic substances will produce positive tests. The Pearl-Benson test is calibrated in terms of SWL having 10 percent solids. In effect, then, it expresses the dilution of 10 percent SWL expressed in parts per million by volume. Hence, a P-B reading of 15 ppm represents only 1.5 mg/l of total solids in the original SWL. For this reason, Gunter and McKee (2415) proposed the term "Pearl-Benson Index" or "PBI" to describe the concentrations measured by this test.

2. Cross References. Sulfur and Sulfur Compounds.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The controlling factor for SWL in streams that may be used for domestic water supply appears to be taste and odor. To eliminate the taste of SWL, a dilution of 1:25,000 appears to be necessary (7). At such dilutions, the concentrations of other potential pollutants from SWL are insignificant.

b. Fish and Other Aquatic Life. The principal deleterious effect of SWL towards fish appears to be its high BOD, with resultant oxygen depletion. Dilutions of 1:200 or better are required to prevent serious oxygen depletion. (673). Compared with Kraft mill effluents, SWL is relatively non-toxic (683). A second deleterious effect arises from the fact that the sugars in SWL stimulate the growth of *Sphaerotilus* in streams (2500, 2642).

Most of the references dealing with the effect of SWL on fish express their findings in terms of dilution. Since the strength of the SWL is seldom given, results cannot be compared exactly; but it is logical to assume that the SWL was approximately 10 percent solids. The following table summarizes the observed effects of SWL on fish:

Given Dilution (ppm by volume)	Type of Fish	Observed Effect	Reference
50-75	—	No effect	3503
500-600	—	Threshold of lethality, 30 days	2642
530-1550	Pink salmon	5 percent kill	3695
560-1175	Chinook salmon	5 percent kill	3695
509-1022	Young herring	Tolerance level	3694
805	Chinook salmon	TL_m for 30 days	3524
880	Chum salmon	Toxic threshold	2091
1000	Trout	Lethal in a few days	673
1015-1230	Silver salmon	5 percent kill	3695
1330-2000	Trout	Lethal	359
1700	Coho salmon	TL_m for 30 days	3524
2000	Salmon	Avoidance reaction	3524
2000-5000	~~Warm-water fish~~	Survived 10-20 days	673
5000	Mixed	No deaths in 28 days	311, 688
5000	Fish	Toxic	687
8330-20,000	Trout fry, perch, and bass	Killed in 29-113 hours in non-aerated water	808
10,000	Bass	Not killed in 17 days in aerated water	808
20,000	Salmon fry	Killed in 28 hours	311, 688
100,000	Fish	Lethal	540
100,000	Rock bass	Lethal	359

Long exposures to SWL affect the internal organs of fish, with definite damage at dilutions of 1:100,000. Moreover, SWL gives a taste to fish flesh (7).

Very little quantitative information is available upon which to assess the effects of SWL on fish-food organisms. In general, it appears that SWL exerts no direct toxic action except at concentrations in excess of 1000 ppm by volume of 10 percent SWL. The sparse literature in this subject has been reviewed and summarized by Gunter and McKee (2415). Lasater (3694) found that some copepods could not tolerate SWL, with significant mortalities being reported at 50-157 ppm of 10 percent SWL in 2 to 14 days.

c. Shellfish Culture. On the basis of a comprehensive literature review, Gunter and McKee (2415) recommended that the Pearl-Benson index attributable to SWL in waters overlying beds for the growing of Olympia oysters should not exceed 10 during the months of April through October and 20 during the months of November through March. In waters overlying beds of the Pacific oyster, the PBI should not exceed 40 during April through October nor 80 during November through March. There appears to be some evidence that PBI concentrations of 8 to 16 are inimical to the adult Olympia oyster and perhaps the threshold concentration for adverse effects is even lower. Adult-Pacific oysters appear to be far more tolerant of SWL than Olympias. It is apparent that Pacifics can withstand PBI concentrations of 50 to 100, or perhaps even more, over long periods of time without mortality.

Toward oyster larvae, on the other hand, SWL may be more adverse toward Pacifics than towards Olympia, owing to the difference in spawning mechanisms. For Pacific larvae, PBI values of 8 to 16 represent a tentative threshold of toxicity. In recent work, Lindsay, Westley, and Woelke (3696) point out that the reproductive cycle of Olympia oysters was affected by fresh ammonia-base SWL at PBI values of 2, 4, and 8; but these effects were not demonstrated as being necessarily adverse. The development of Pacific larvae was affected at PBI values of 2 and greater, and at 18 almost 100 percent of the larvae were abnormal. These authors also point out that SWL is lethal to *Monas sp*, an important oyster food organism at P-B indices of 1,000 to 10,000. Over several months, SWL appears to have a depressing effect on this food organism at PBI values as low as 2.5.

Ministry of the Environment
Ministère de l'Environnement
Ontario

135 St. Clair Avenue West
Suite 100
Toronto, Ontario
M4V 1P5

135 ouest, avenue St. Clair
Bureau 100
Toronto (Ontario)
M4V 1P5

September 18, 1985

Mr. J.J. Armstrong
Head, Technical Policy Section
Environmental Office, MTC
1201 Wilson Ave.
Downsview, Ontario
M3M 1J8

Dear Mr. Armstrong:

Re: Use of Tembind Road Dust Suppressant
on Leo Lake Road

As a result of the meeting held on 16 May, 1985 between MOE, MTC, Can Am Oil Services and Temfibre Inc., to discuss Tembind dust suppressant, a gravel road was treated with the product to test both its efficiency and potential for environmental impairment.

The test road, selected by Can-Am Oil Services, is known as Leo Lake Road, and is about 3 km long, running off Highway 15, 8 km north of Joyceville in S.E. Ontario. The road curves and undulates steeply with few level stretches, and at one point crosses a waterway served by a large culvert. At this point, the road approaches the water to within 1 metre on either side. This particular area was considered good for test purposes, being highly sensitive to dust suppressant overspray or run-off. In upcoming MOE guidelines for the use of road dust suppressants, application of chemicals in such sensitive areas is discouraged. However, for test purposes, the Tembind suppressant was allowed to be sprayed in this location.

Personnel present during the day of the test, June 7, 1985, were the writer, Mr. Murray Cressman of Can-Am Oil Services, Mr. Fred Scott of the township, Mr. Bruce Metcalfe of the MOE Kingston District Office and a representative of the MTC.

Prior to spraying the Tembind, the road was graded. MOE staff sampled the waterway described above to provide background water quality data. Tembind was then sprayed along the length of the road at a rate of approximately 1.5 L/m^2. Visual observations showed that overspray was negligible to non-existant and that the Tembind soaked into, or adhered readily to the road surface, and within 20-30 minutes a vehicle could drive the road with little or no chemical "pick-up". No evidence of run-off or overspray was seen at the water crossing. In addition, although a little odour was noted after spraying the chemical, it could be described as being similar to that of fresh cardboard and not particularly offensive. An hour after Tembind application, the waterway was again sampled by the MOE in the chance that some chemical may have entered the water through subterranean channeling, or short circuit.

Since the test, Mr. Metcalfe of the MOE has visually inspected the road several times over a period of about 2 months and has seen no evidence of run-off. Due to the extremely dark colour of the Tembind, it might be safe to suppose that even with rain dilution, some evidence of surface run-off would be seen. On July 18, 1985, after a particularly heavy rainfall, reportedly the first significant rain since applying Tembind, the water at the road crossing was again sampled. The results of both pre and post Tembind application water samples are shown in the table. It was difficult to select analytical parameters for the samples due to lack of experience with the Tembind. However, due to the strong organic nature of the chemical and the known presence of ammonia, or ammonium compounds, the total Kjeldahl nitrogen test (TKN), the ammonia test (NH_3), the dissolved organic carbon test (DOC), and the dissolved inorganic carbon test (DIC), were felt to be appropriate indicators.

... 3

TABLE OF ANALYTICAL RESULTS

SAMPLE	TKN	NH_3	DOC	DIC	
Before Application 7/6/85	0.48	0.05	4.8	16.0	
1 Hour After Application 7/6/85	0.63	0.09	5.3	16.6)	2 locations
	0.47	0.05	4.6	15.8)	
5 Weeks After Application 18/07/85	0.48	0.04	4.7	14.4)	3 locations
	0.50	0.04	4.6	14.8)	
	0.59	0.07	4.9	15.0)	

All results in mg/L

TKN and NH_3 are expressed as

N - nitrogen, and not as the entire molecule(s)

... 4

While the results vary slightly from place to place, they typify the range of results generally seen on multiple samples in work of this nature, and show no evidence of contamination from an outside source.

Although the test can not be considered entirely definitive, (that would require many weeks of very intensive groundwater and surface water monitoring and analyses, tracer studies, etc.), I feel it served as a good indication that no environmental effect or impairment was measurable at the location under the conditions of the test.

In addition to on-site testing, a sample of Tembind obtained directly from the truck, was returned to the MOE Toronto laboratory for microbiological testwork. Ames tests showed that Tembind is toxic but non-mutagenic to bacteria. While many substances can prove toxic to bacteria if present in high enough concentrations, the mutagenicity test is perhaps of more significatnce as a positive result could have precluded the use of Tembind as a road dust suppressant.

Further biological tests on Tembind are planned, including its toxicity to higher aquatic life forms and fish. Results will be forwarded to you as they become available.

In the meantime, results form this test indicated that there is no good reason to prohibit the use of Tembind as a road dust suppressant and suggest its use may continue unless future experience shows otherwise. The Waste Management Branch is planning a further study to assess the off site impact of applying various dust suppressants. Results from that study will be used to determine the viability of long-term use of various liquid industrial wastes as dust suppressants.

Yours truly,

John Smart
PROJECT Officer
Waste Management Branch

JS/sp
IN 06 18
1899L

APPENDIX G

RESULTS OF DUSTFALL MONITORING PROGRAM

APPENDIX G

LIST OF FIGURES

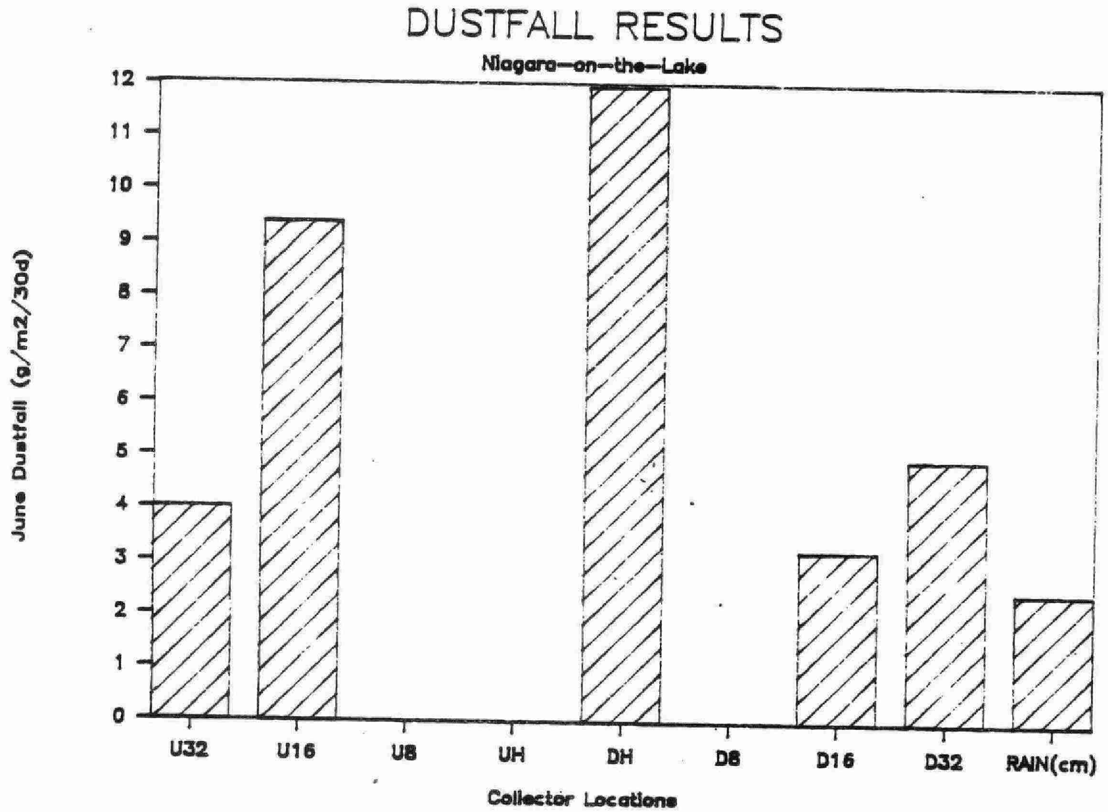
DUST SUPPRESSION DUSTFALL RESULTS JUNE 87 (P8037.00)

		JAR I.D.	DATE INSTALLED	DATE COLLECTED	DUST (G/M^2/30 DAYS)	DEPTH (CM)
Location	NOTL	U32	MAY 22/87	JUNE 18/87	4.03	
Date	JUNE 18/87	U16	MAY 22/87	JUNE 18/87	9.39	
Windspeed	5 knots	DH	MAY 22/87	JUNE 18/87	11.95	
Wind Dir	NNW	D16	MAY 22/87	JUNE 18/87	3.23	
Humidity	51%	D32	MAY 22/87	JUNE 18/87	4.96	
Rating	3/10		MAY 22/87	JUNE 18/87		2.5
Moisture	2.0%					
Location	MILTON	U32	MAY 29/87	JUNE 19/87	2.35	
Date	JUNE 19/87	U16	MAY 29/87	JUNE 19/87	1.17	
Windspeed	4 knots	U8	MAY 29/87	JUNE 19/87	2.33	
Wind Dir	NW	UH	MAY 29/87	JUNE 19/87	1.44	
Humidity	57%	DH	MAY 29/87	JUNE 19/87	2.96	
Rating	9/10	D8	MAY 29/87	JUNE 19/87	2.15	
Moisture	6.0%	D16	MAY 29/87	JUNE 19/87	2.64	
		D32	MAY 29/87	JUNE 19/87	1.65	
			MAY 29/87	JUNE 19/87		1.9
Location	HALLOWELL	U32	MAY 25/87	JUNE 20/87	38.51	
Date	JUNE 20/87	U16	MAY 25/87	JUNE 20/87	0.00	
Windspeed	3 knots	U8	MAY 25/87	JUNE 20/87	46.77	
Wind Dir	NW	UH	MAY 25/87	JUNE 20/87	33.37	
Humidity	54%	DH	MAY 25/87	JUNE 20/87	53.76	
Rating	6/10	D8	MAY 25/87	JUNE 20/87	15.54	
Moisture	1.0%	D16	MAY 25/87	JUNE 20/87	2.86	
		D32	MAY 25/87	JUNE 20/87	12.30	
			MAY 25/87	JUNE 20/87		3.6

		JAR I.D.	DATE INSTALLED	DATE COLLECTED	DUST (G/M^2/30 DAYS)	DEPTH (CM)
Location	NOTL	U32	JUNE 18/87	JULY 21/87	10.03	
Date	JULY 21/87	U16	JUNE 18/87	JULY 21/87	11.12	
Windspeed	0-5 knots	DH	JUNE 18/87	JULY 21/87	13.13	
Wind Dir	NW	D16	JUNE 18/87	JULY 21/87	1.98	
Humidity	62%	D32	JUNE 18/87	JULY 21/87	8.59	
Rating	8/10		JUNE 18/87	JULY 21/87		13.5
Moisture	3.0%					
Location	MILTON	U32	JUNE 19/87	JULY 22/87	8.41	
Date	JULY 22/87	U16	JUNE 19/87	JULY 22/87	18.03	
Windspeed	3 knots	U8	JUNE 19/87	JULY 22/87	21.82	
Wind Dir	NW	UH	JUNE 19/87	JULY 22/87	21.78	
Humidity	72%	DH	JUNE 19/87	JULY 22/87	22.29	
Rating	9/10	D8	JUNE 19/87	JULY 22/87	23.05	
Moisture	3.0%	D16	JUNE 19/87	JULY 22/87	6.56	
		D32	JUNE 19/87	JULY 22/87	15.12	
			JUNE 19/87	JULY 22/87		21.7
Location	HALLOWELL	U32	JUNE 20/87	JULY 19/87	8.87	
Date	JULY 19/87	U16	JUNE 20/87	JULY 19/87	5.09	
Windspeed	0-4 knots	U8	JUNE 20/87	JULY 19/87	31.38	
Wind Dir	SE	UH	JUNE 20/87	JULY 19/87	23.20	
Humidity	53%	DH	JUNE 20/87	JULY 19/87	34.01	
Rating	6/10	D8	JUNE 20/87	JULY 19/87	27.07	
Moisture	0.2%	D16	JUNE 20/87	JULY 19/87	23.00	
		D32	JUNE 20/87	JULY 19/87	22.86	
			JUNE 20/87	JULY 19/87		7.0
Location	COLEMAN	U32	JUNE 24/87	JULY 25/87	6.20	
Date	JULY 25/87	U16	JUNE 24/87	JULY 25/87	9.85	
Windspeed	0-5 knots	U8	JUNE 24/87	JULY 25/87	8.19	
Wind Dir	NE	UH	JUNE 24/87	JULY 25/87	32.68	
Humidity	60%	D8	JUNE 24/87	JULY 25/87	26.78	
Rating	6/10	D16	JUNE 24/87	JULY 25/87	20.01	
Moisture	4.0%	D32	JUNE 24/87	JULY 25/87	11.42	
			JUNE 24/87	JULY 25/87		7.5
Location	JACK LAKE	U16	JUNE 25/87	JULY 26/87	4.51	
Date	JULY 26/87	U8	JUNE 25/87	JULY 26/87	2.67	
Windspeed	2-6 knots	UH	JUNE 25/87	JULY 26/87	8.31	
Wind Dir	NW	DH	JUNE 25/87	JULY 26/87	5.35	
Humidity	59%	D8	JUNE 25/87	JULY 26/87	11.26	
Rating	8/10	D16	JUNE 25/87	JULY 26/87	2.07	
Moisture	1.3%	D32	JUNE 25/87	JULY 26/87	3.57	
			JUNE 25/87	JULY 26/87		3.4
Location	WOODSTOCK	U32	JUNE 30/87	JULY 23/87	11.54	
Date	JULY 23/87	U16	JUNE 30/87	JULY 23/87	12.88	
Windspeed	4-7 knots	U8	JUNE 30/87	JULY 23/87	14.20	
Wind Dir	SW	UH	JUNE 30/87	JULY 23/87	25.70	
Humidity	54%	DH	JUNE 30/87	JULY 23/87	33.14	
Rating	2/10	D8	JUNE 30/87	JULY 23/87	7.10	
Moisture	2.0%	D16	JUNE 30/87	JULY 23/87	12.22	
		D32	JUNE 30/87	JULY 23/87	10.40	
			JUNE 30/87	JULY 23/87		9.0

		JAR I.D.	DATE INSTALLED	DATE COLLECTED	DUST (G/M^2/30 DAYS)	DEPTH (CM)
Location	NOTL	U32	JULY 21/87	AUG 24/87	7.03	
Date	AUG 24/87	U16	JULY 21/87	AUG 24/87	11.05	
Windspeed	0-5 knots	DH	JULY 21/87	AUG 24/87	26.46	
Wind Dir	W	D16	JULY 21/87	AUG 24/87	6.42	
Humidity	64%	D32	JULY 21/87	AUG 24/87	8.75	
Rating	4/10		JULY 21/87	AUG 24/87		10.3
Moisture	1%					
Location	MILTON	U32	JULY 22/87	SEPT 1/87	6.34	
Date	SEPT 1/87	U16	JULY 22/87	SEPT 1/87	11.42	
Windspeed	1-4 knots	U8	JULY 22/87	SEPT 1/87	6.65	
Wind Dir	NW	UH	JULY 22/87	SEPT 1/87	11.46	
Humidity	76%	DH	JULY 22/87	SEPT 1/87	13.33	
Rating	9/10	D8	JULY 22/87	SEPT 1/87	12.01	
Moisture	3%	D16	JULY 22/87	SEPT 1/87	3.46	
		D32	JULY 22/87	SEPT 1/87	2.99	
			JULY 22/87	SEPT 1/87		16.5
Location	HALLOWELL	U32	JULY 19/87	AUG 30/87	18.67	
Date	AUG 30/87	U16	JULY 19/87	AUG 30/87	8.27	
Windspeed	2-7 knots	U8	JULY 19/87	AUG 30/87	6.77	
Wind Dir	SW	UH	JULY 19/87	AUG 30/87	12.17	
Humidity	76%	DH	JULY 19/87	AUG 30/87	21.10	
Rating	8/10	D8	JULY 19/87	AUG 30/87	5.17	
Moisture	2%	D16	JULY 19/87	AUG 30/87	5.43	
		D32	JULY 19/87	AUG 30/87	0.00	
			JULY 19/87	AUG 30/87		4.5
Location	COLEMAN	U32	JULY 25/87	AUG 27/87	2.31	
Date	AUG 27/87	U16	JULY 25/87	AUG 27/87	2.59	
Windspeed	0-3 knots	U8	JULY 25/87	AUG 27/87	4.20	
Wind Dir	SE - SW	UH	JULY 25/87	AUG 27/87	10.67	
Humidity	66%	D8	JULY 25/87	AUG 27/87	5.25	
Rating	4/10	D16	JULY 25/87	AUG 27/87	3.75	
Moisture	1%	D32	JULY 25/87	AUG 27/87	3.37	
			JULY 25/87	AUG 27/87		3.2
Location	JACK LAKE	U16	JULY 26/87	AUG 26/87	7.22	
Date	AUG 26/87	U8	JULY 26/87	AUG 26/87	4.67	
Windspeed	0-2 knots	UH	JULY 26/87	AUG 26/87	11.91	
Wind Dir	N	DH	JULY 26/87	AUG 26/87	7.53	
Humidity	54%	D8	JULY 26/87	AUG 26/87	6.70	
Rating	8/10	D16	JULY 26/87	AUG 26/87	5.42	
Moisture	2%	D32	JULY 26/87	AUG 26/87	0.00	
			JULY 26/87	AUG 26/87		7.7
Location	WOODSTOCK	U32	JULY 23/87	AUG 25/87	4.58	
Date	AUG 25/87	U16	JULY 23/87	AUG 25/87	5.77	
Windspeed	0-3 knots	U8	JULY 23/87	AUG 25/87	12.95	
Wind Dir	NW	UH	JULY 23/87	AUG 25/87	9.62	
Humidity	54%	DH	JULY 23/87	AUG 25/87	9.61	
Rating	2/10	D8	JULY 23/87	AUG 25/87	10.79	
Moisture	2%	D16	JULY 23/87	AUG 25/87	19.90	
		D32	JULY 23/87	AUG 25/87	15.29	
			JULY 23/87	AUG 25/87		14.7

		JAR I.D.	DATE INSTALLED	DATE COLLECTED	DUST (G/M^2/30 DAYS)	DEPTH (CM)
Location	NOTL	U32	AUG 24/87	OCT 14/87	0.00	
Date	OCT 14/87	U16	AUG 24/87	OCT 14/87	0.00	
Windspeed	5-10 knots	DH	AUG 24/87	OCT 14/87	22.00	
Wind Dir	SSW	D16	AUG 24/87	OCT 14/87	0.00	
Humidity	60%	D32	AUG 24/87	OCT 14/87	1.54	
Rating	4/10		AUG 24/87	OCT 14/87		0.0
Moisture	3%					
Location	MILTON	U32	SEPT 1/87	OCT 6/87	0.89	
Date	OCT 6/87	U16	SEPT 1/87	OCT 6/87	0.87	
Windspeed	5-10 knots	U8	SEPT 1/87	OCT 6/87	3.07	
Wind Dir	WSW - W	UH	SEPT 1/87	OCT 6/87	5.66	
Humidity	91%	DH	SEPT 1/87	OCT 6/87	16.98	
Rating	8/10	D8	SEPT 1/87	OCT 6/87	9.55	
Moisture	4%	D16	SEPT 1/87	OCT 6/87	3.20	
		D32	SEPT 1/87	OCT 6/87	5.27	
			SEPT 1/87	OCT 6/87		11.2
Location	HALLOWELL	U32	AUG 30/87	SEPT 28/87	0.00	
Date	SEPT 28/87	U16	AUG 30/87	SEPT 28/87	14.53	
Windspeed	5 knots	U8	AUG 30/87	SEPT 28/87	25.25	
Wind Dir	SSW	UH	AUG 30/87	SEPT 28/87	33.16	
Humidity	57%	DH	AUG 30/87	SEPT 28/87	40.94	
Rating	4/10	D8	AUG 30/87	SEPT 28/87	11.05	
Moisture	6%	D16	AUG 30/87	SEPT 28/87	4.60	
		D32	AUG 30/87	SEPT 28/87	6.33	
			AUG 30/87	SEPT 28/87		11.2
Location	COLEMAN	U32	AUG 27/87	OCT 2/87	2.48	
Date	OCT 2/87	U16	AUG 27/87	OCT 2/87	3.53	
Windspeed	10 knots	U8	AUG 27/87	OCT 2/87	3.74	
Wind Dir	SSW	UH	AUG 27/87	OCT 2/87	8.10	
Humidity	63%	D8	AUG 27/87	OCT 2/87	7.63	
Rating	8.5/10	D16	AUG 27/87	OCT 2/87	5.35	
Moisture	6%	D32	AUG 27/87	OCT 2/87	5.25	
			AUG 27/87	OCT 2/87		4.7
Location	JACK LAKE	U16	AUG 26/87	OCT 1/87	5.60	
Date	OCT 1/87	U8	AUG 26/87	OCT 1/87	2.44	
Windspeed	calm to 10 knots	UH	AUG 26/87	OCT 1/87	9.40	
Wind Dir	SSW	DH	AUG 26/87	OCT 1/87	5.86	
Humidity	50%	D8	AUG 26/87	OCT 1/87	4.17	
Rating	7/10	D16	AUG 26/87	OCT 1/87	2.08	
Moisture	2.5%	D32	AUG 26/87	OCT 1/87	5.16	
			AUG 26/87	OCT 1/87		5.7
Location	WOODSTOCK	U32	AUG 25/87	OCT 5/87	2.01	
Date	OCT 5/87	U16	AUG 25/87	OCT 5/87	3.03	
Windspeed	SSW	U8	AUG 25/87	OCT 5/87	7.31	
Wind Dir	8 to 14 knots	UH	AUG 25/87	OCT 5/87	6.36	
Humidity	50%	DH	AUG 25/87	OCT 5/87	5.67	
Rating	2/10	D8	AUG 25/87	OCT 5/87	4.79	
Moisture	2.5%	D16	AUG 25/87	OCT 5/87	4.23	
		D32	AUG 25/87	OCT 5/87	1.72	
			AUG 25/87	OCT 5/87		11.2



LEGEND

U32 - UPWIND SAMPLER 32m FROM ROAD

U16 - UPWIND SAMPLER 16m FROM ROAD

U8 - UPWIND SAMPLER 8m FROM ROAD

UH - UPWIND SAMPLER ROADSIDE 2.20m HIGH

DH - DOWNWIND SAMPLER ROADSIDE 2.20m HIGH

D8 - DOWNWIND SAMPLER 8m FROM ROAD

D16 - DOWNWIND SAMPLER 16m FROM ROAD

D32 - DOWNWIND SAMPLER 32m FROM ROAD

RAIN (CM) - RAIN GAUGE

Fig. G 1a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - NIAGARA ON THE LAKE, JUNE

ACRES

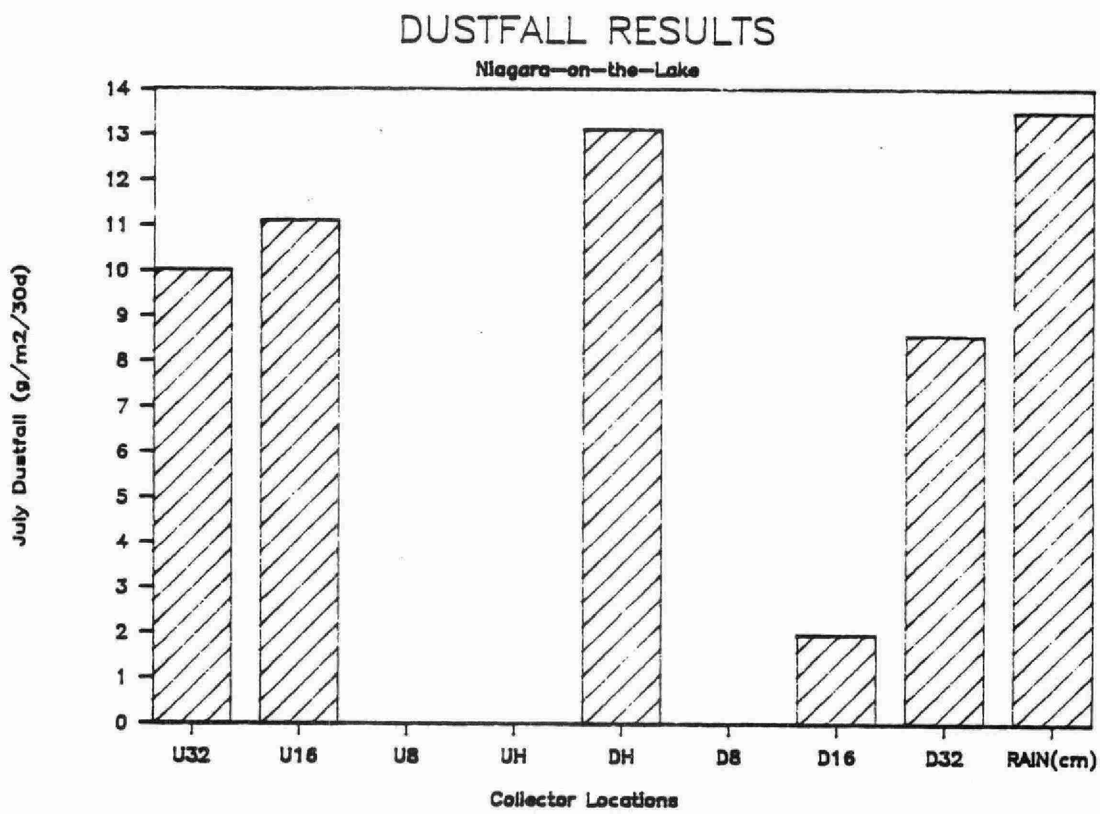


Fig. G 1b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - NIAGARA ON THE LAKE, JULY

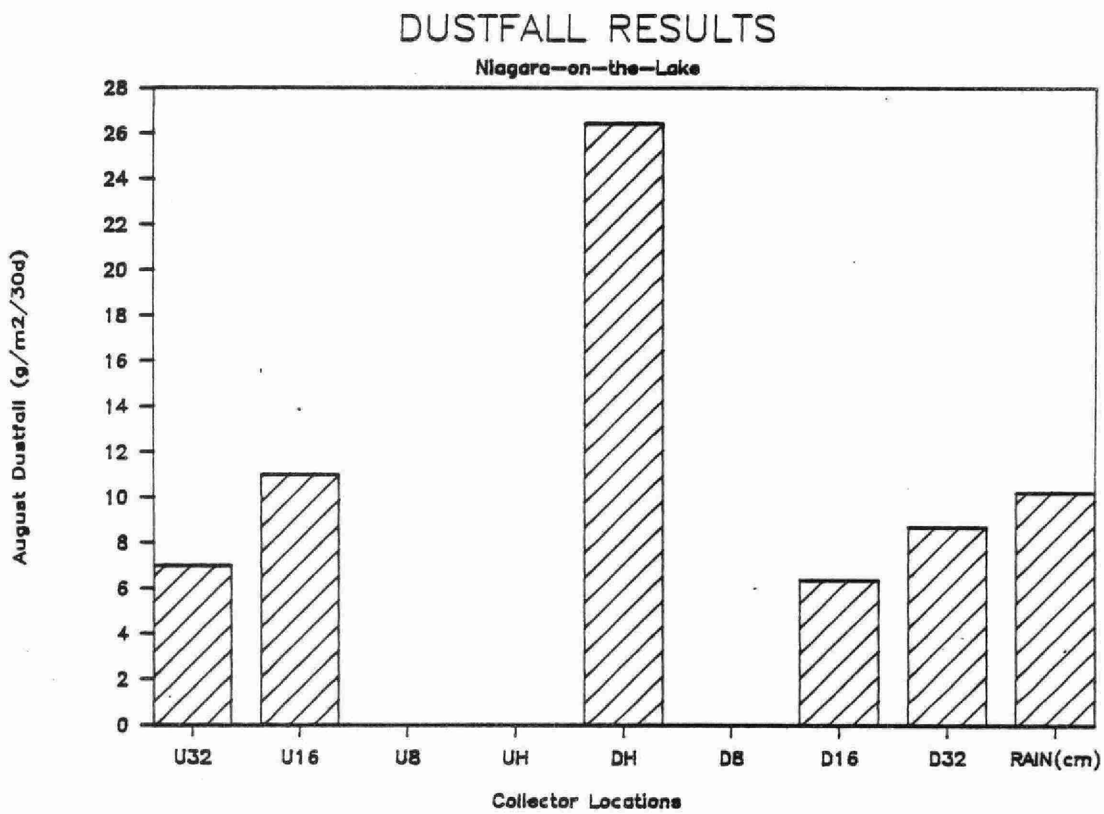


Fig. G 1c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - NIAGARA ON THE LAKE, AUGUST

ACRES

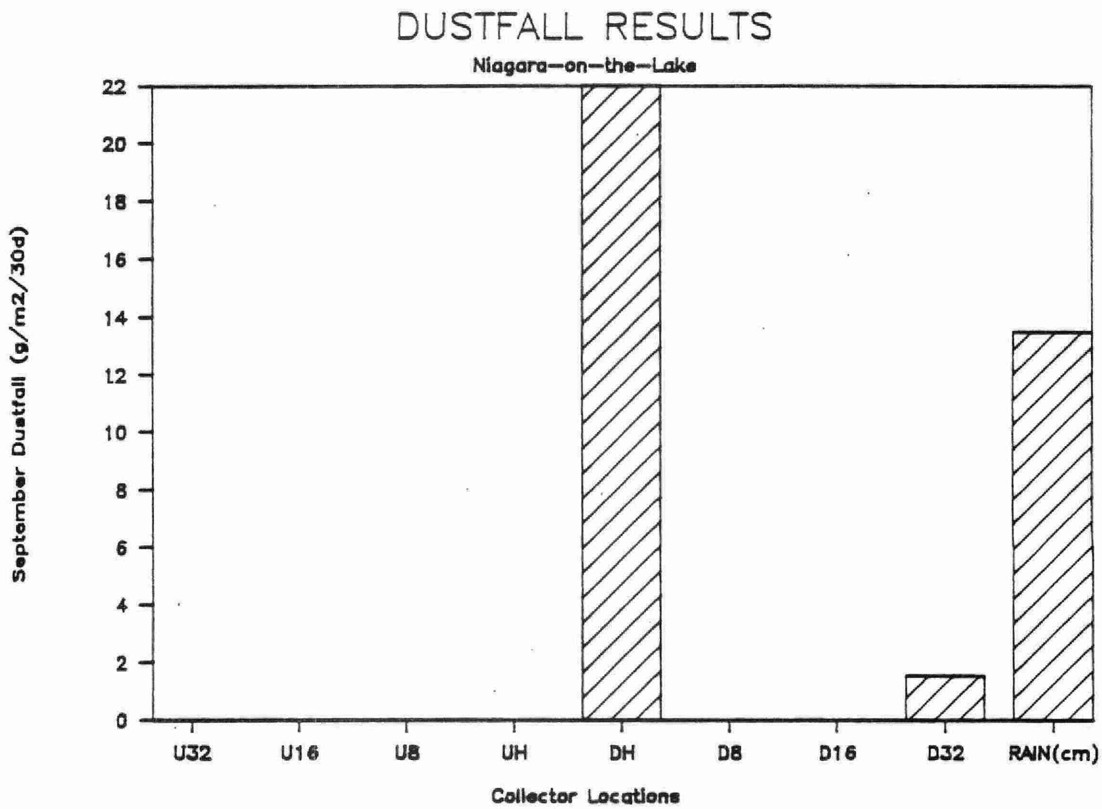


Fig. G 1d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - NIAGARA ON THE LAKE, SEPTEMBER

ACRES

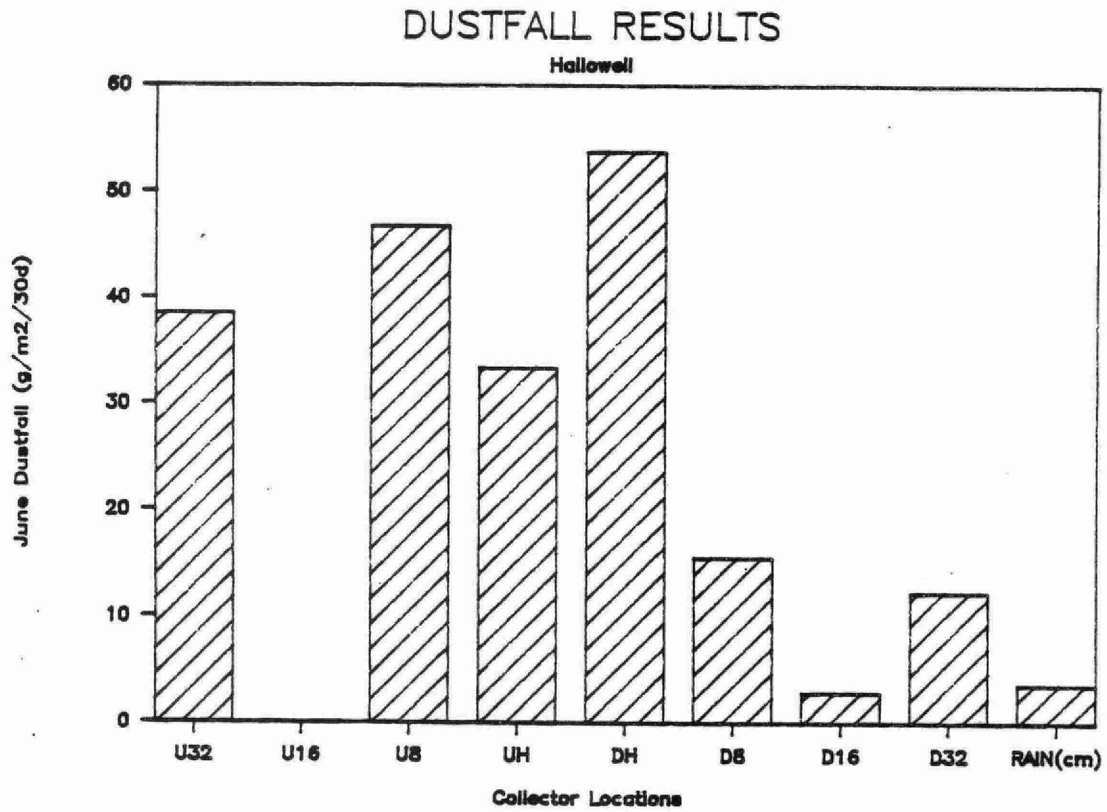


Fig. G 2a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - HALLOWELL, JUNE

ACRES

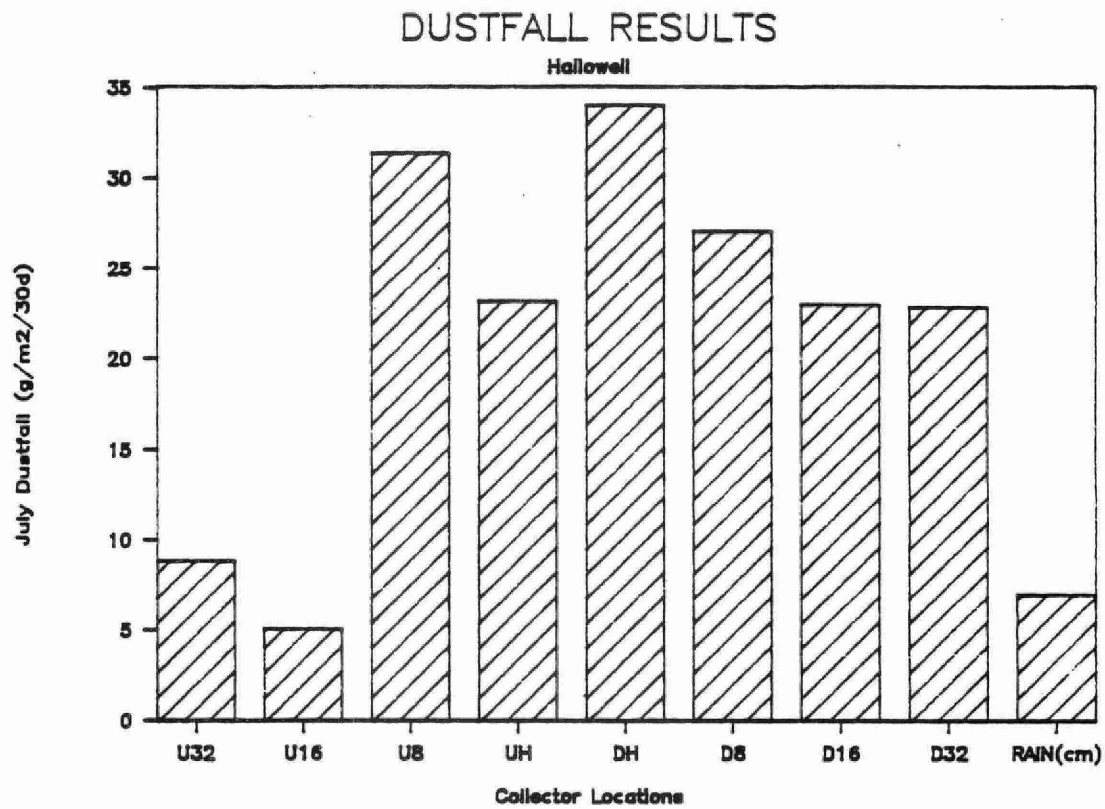


Fig. G 2b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - HALLOWELL, JULY

ACRES

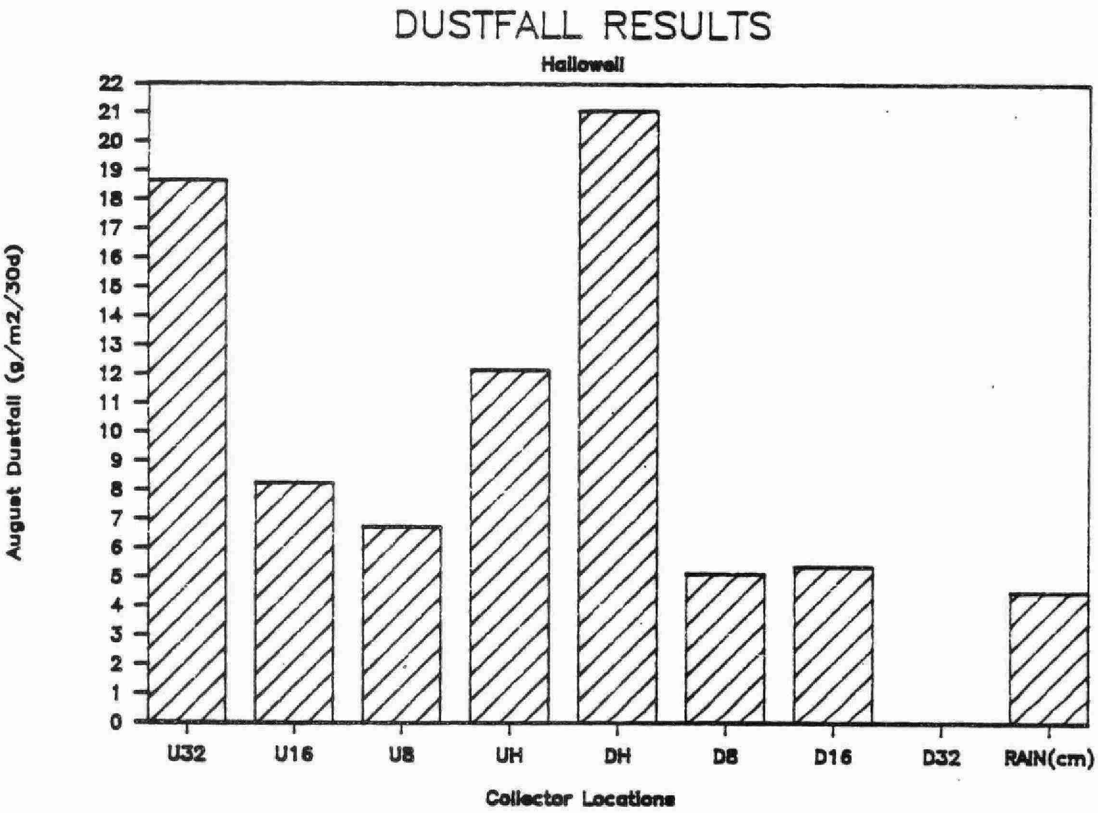


Fig. G 2c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - HALLOWELL, AUGUST

ACRES

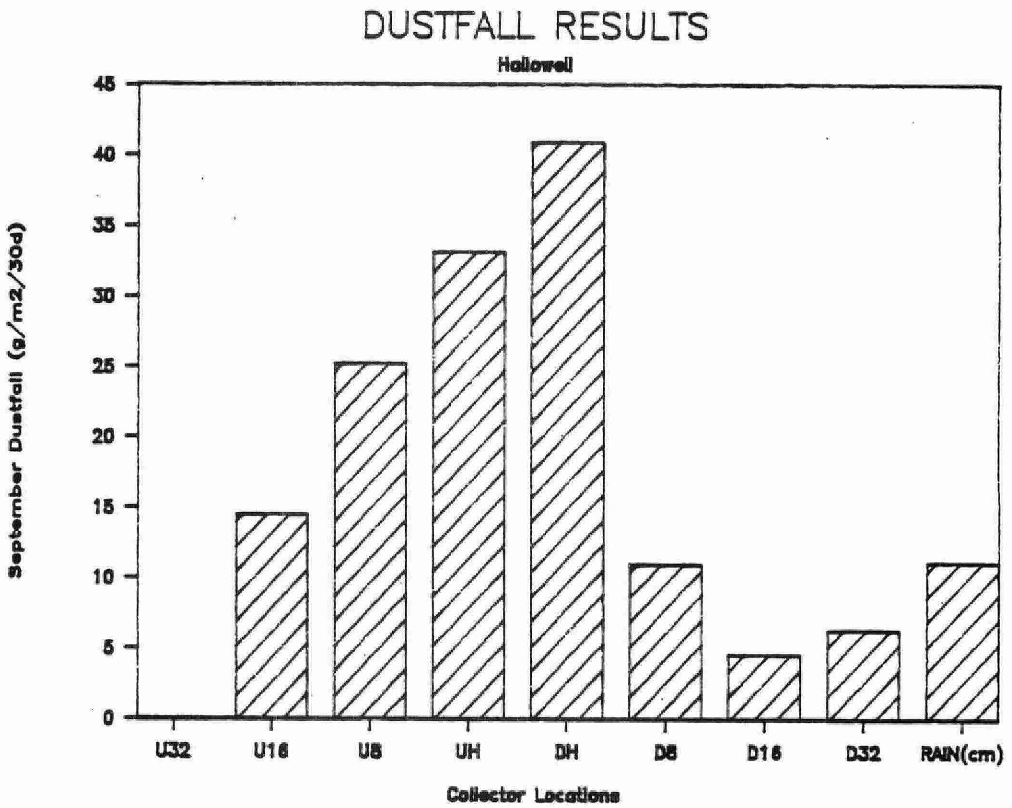


Fig. G 2d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - HALLOWELL, SEPTEMBER

ACRES

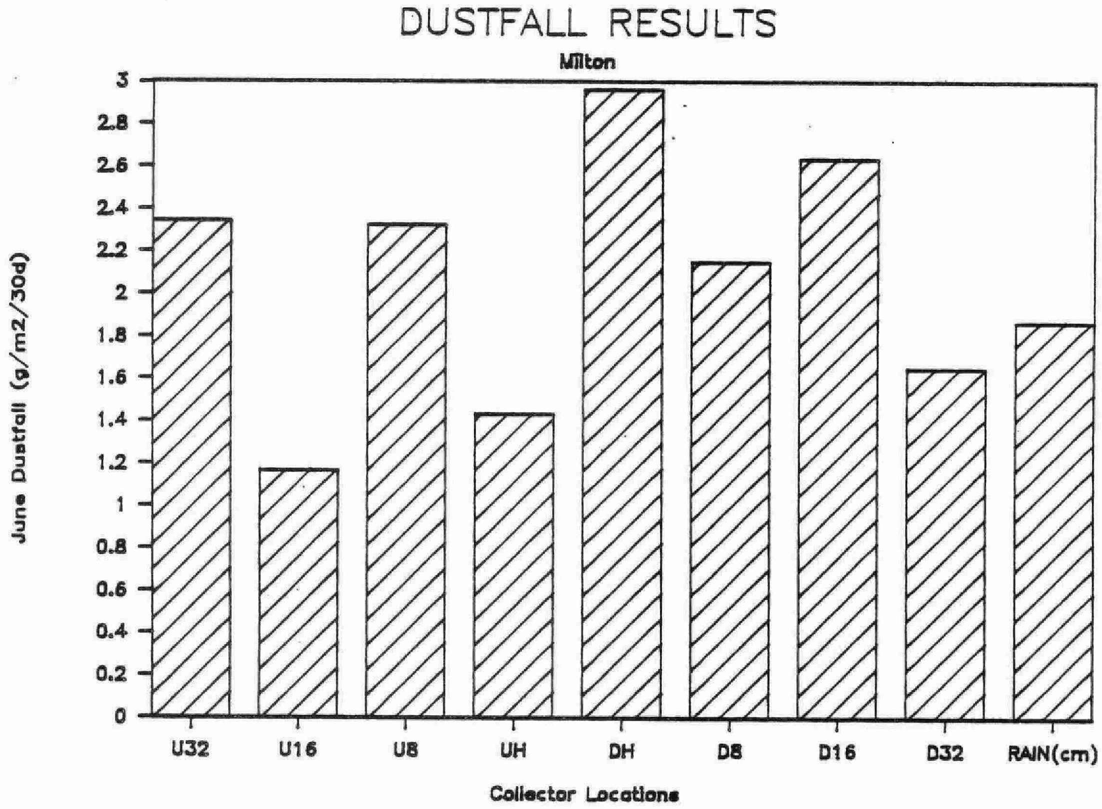


Fig. G 3a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - MILTON, JUNE

ACRES

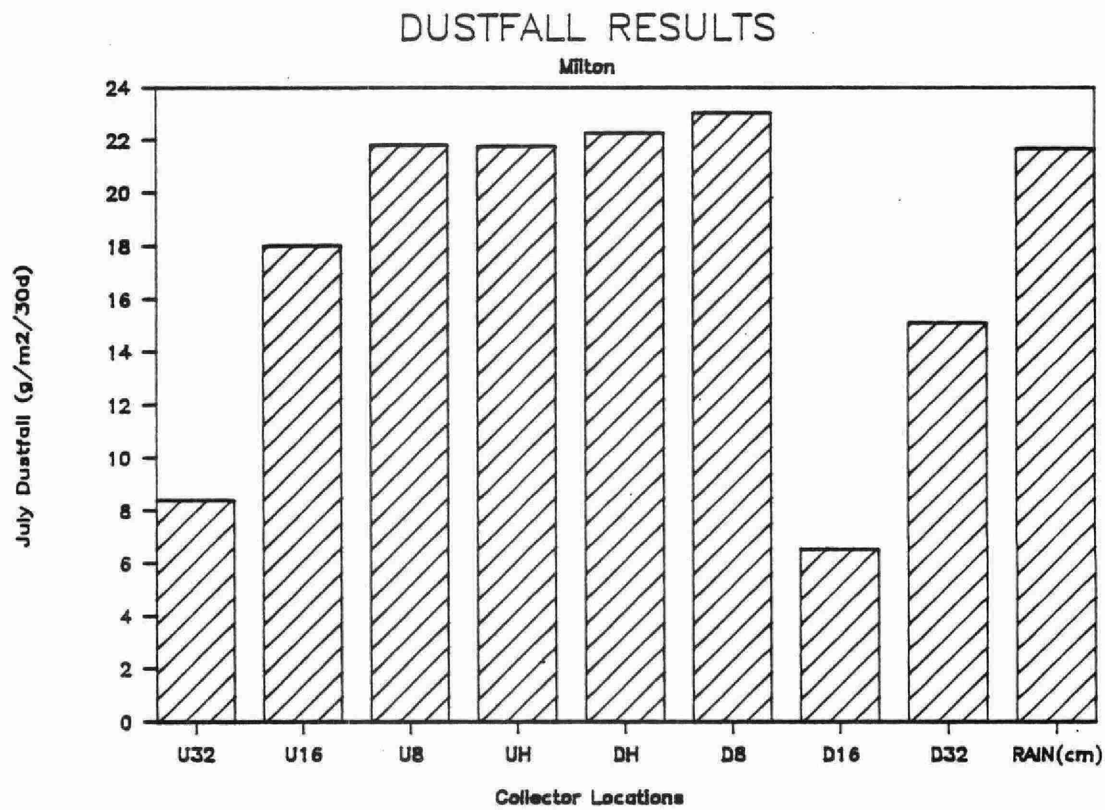


Fig. G 3b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
DUSTFALL RESULTS - MILTON, JULY

ACRES

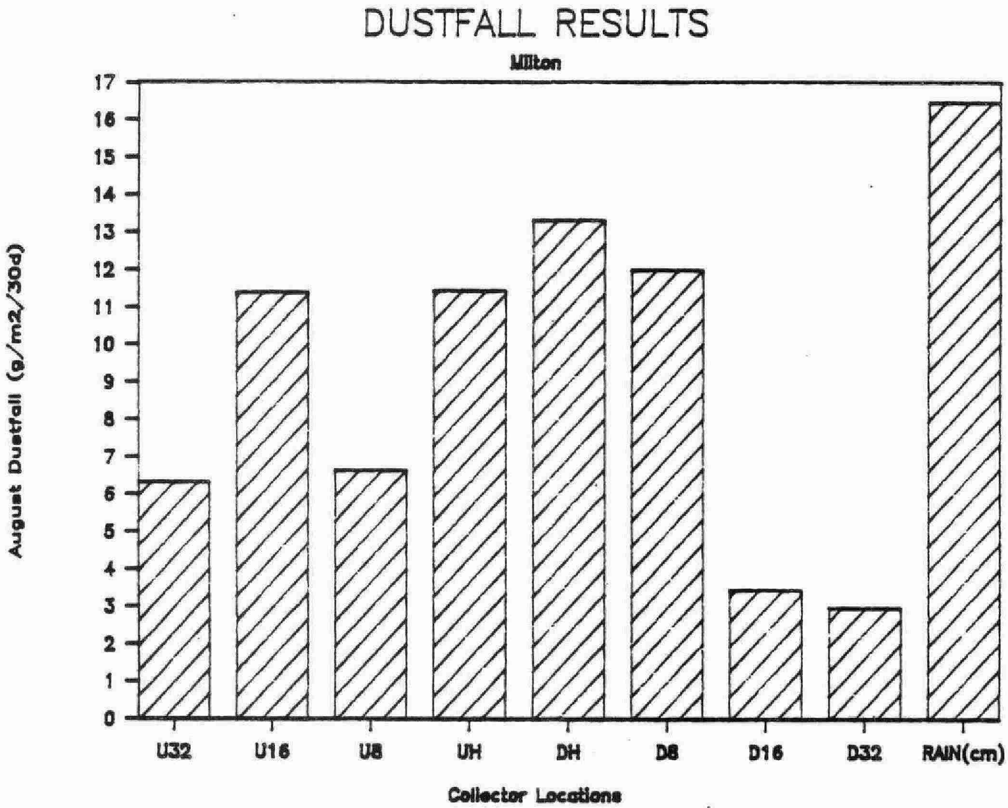


Fig. G 3c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - MILTON, AUGUST

ACRES

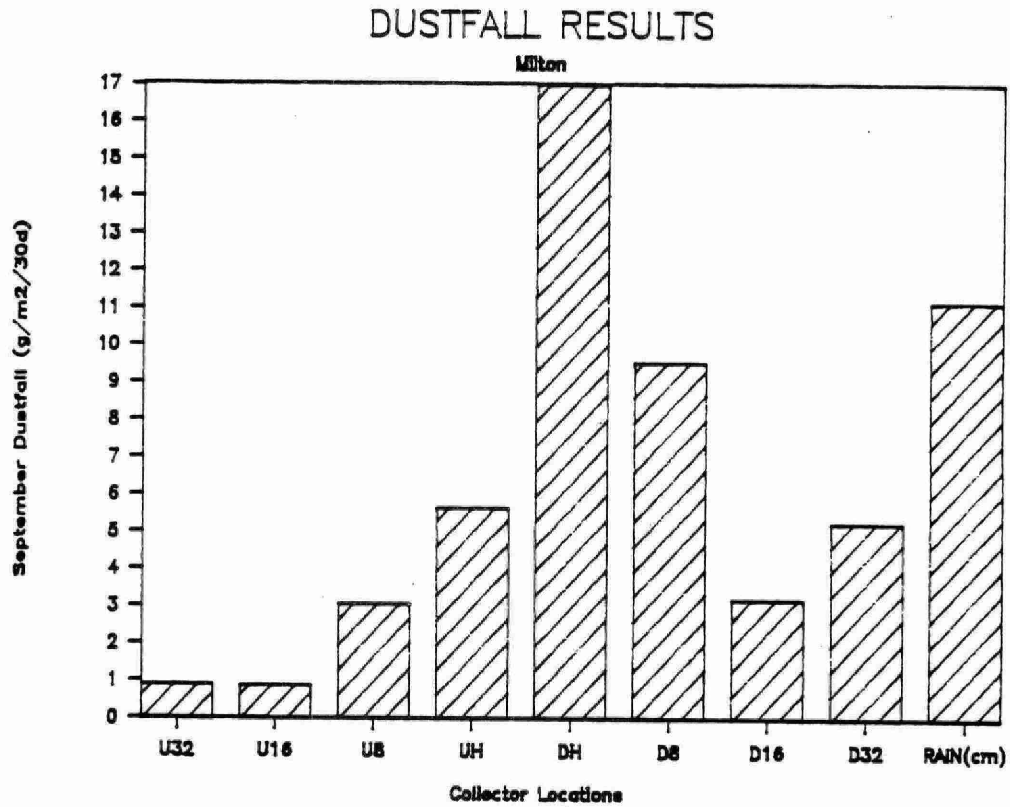


Fig. G 3d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
DUSTFALL RESULTS - MILTON, SEPTEMBER

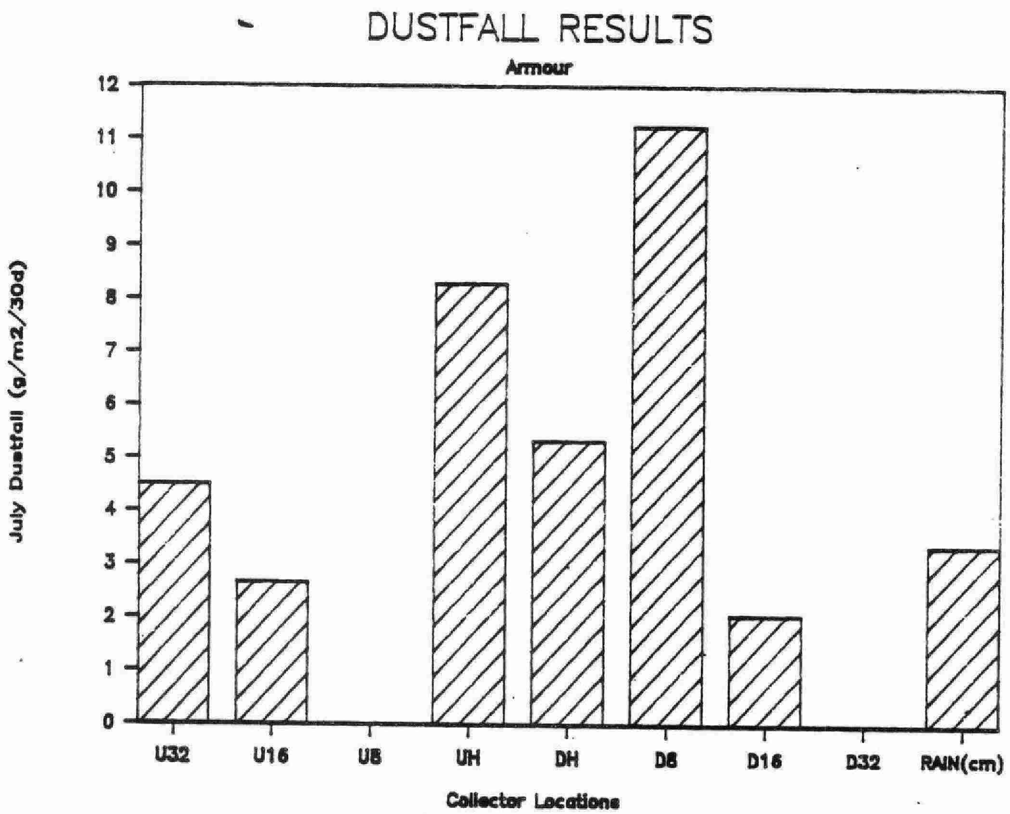


Fig. G 4a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
DUSTFALL RESULTS - ARMOUR, JULY

ACRES

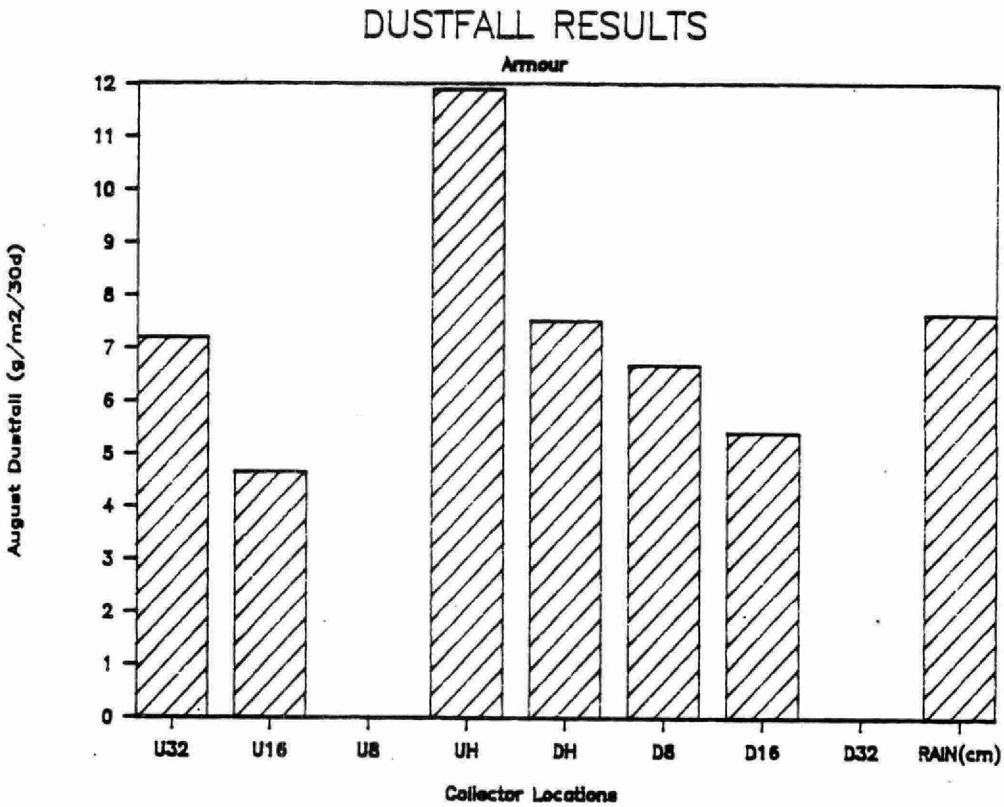


Fig. G 4b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
DUSTFALL RESULTS - ARMOUR, AUGUST

ACRES

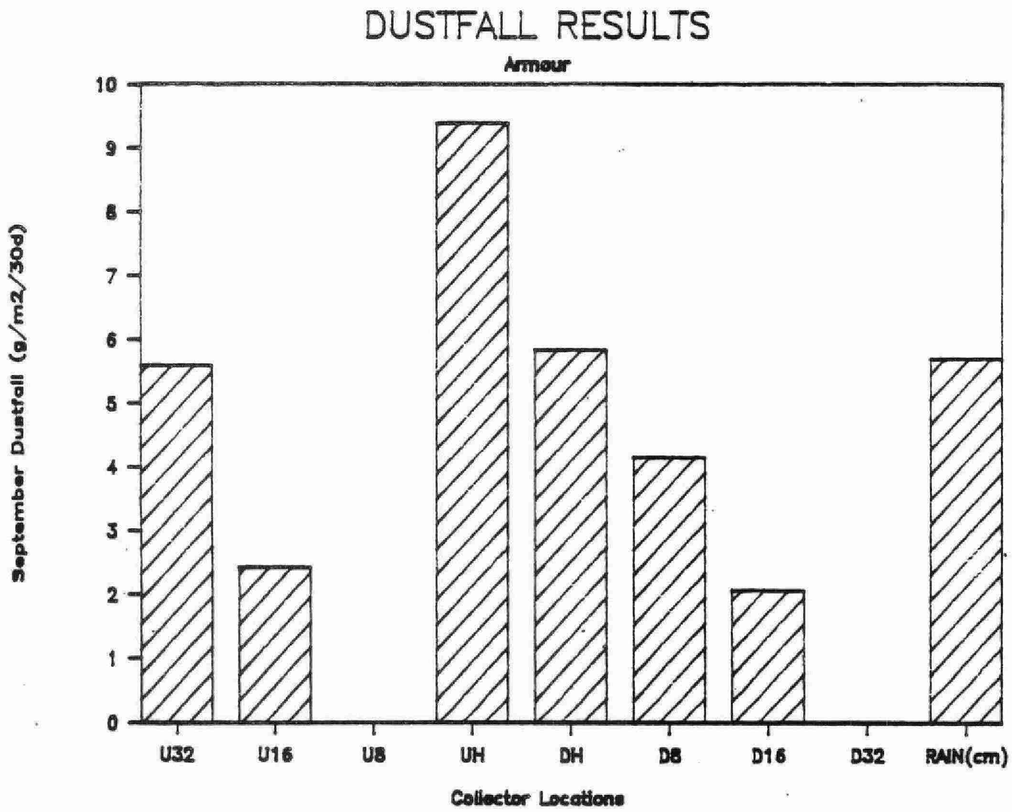


Fig. G 4c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - ARMOUR, SEPTEMBER

ACRES

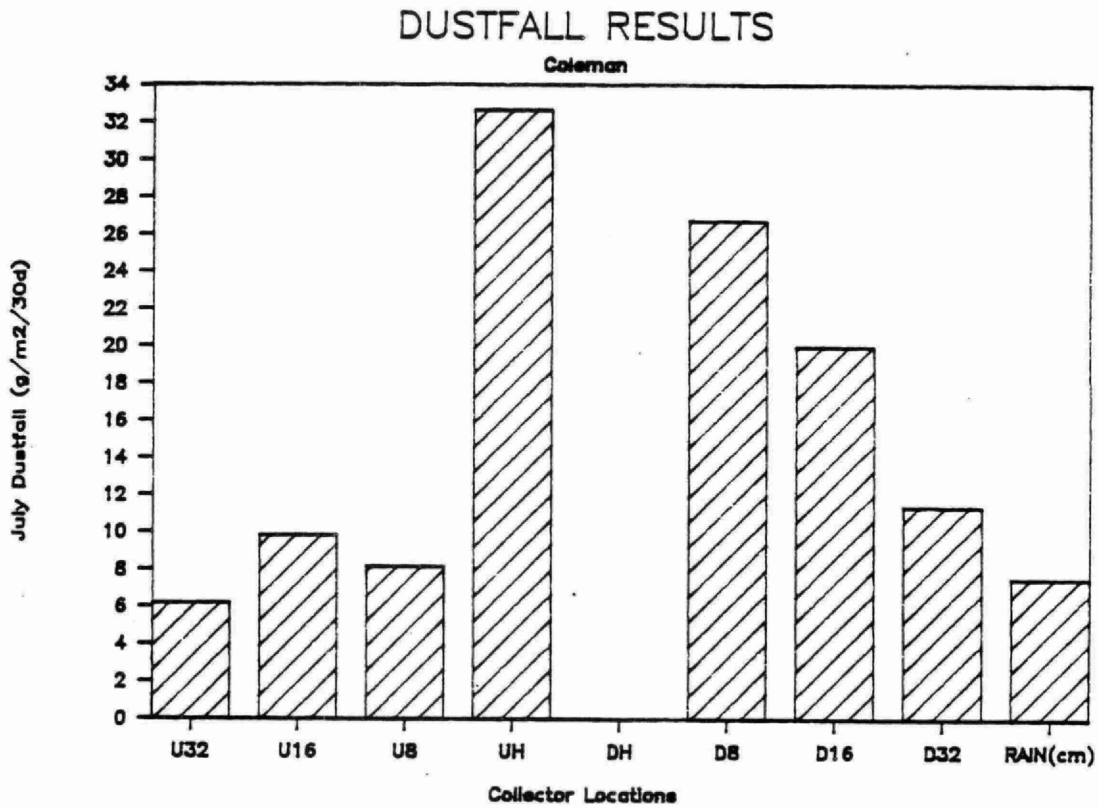


Fig. G 5a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
DUSTFALL RESULTS - COLEMAN, JULY

ACRES

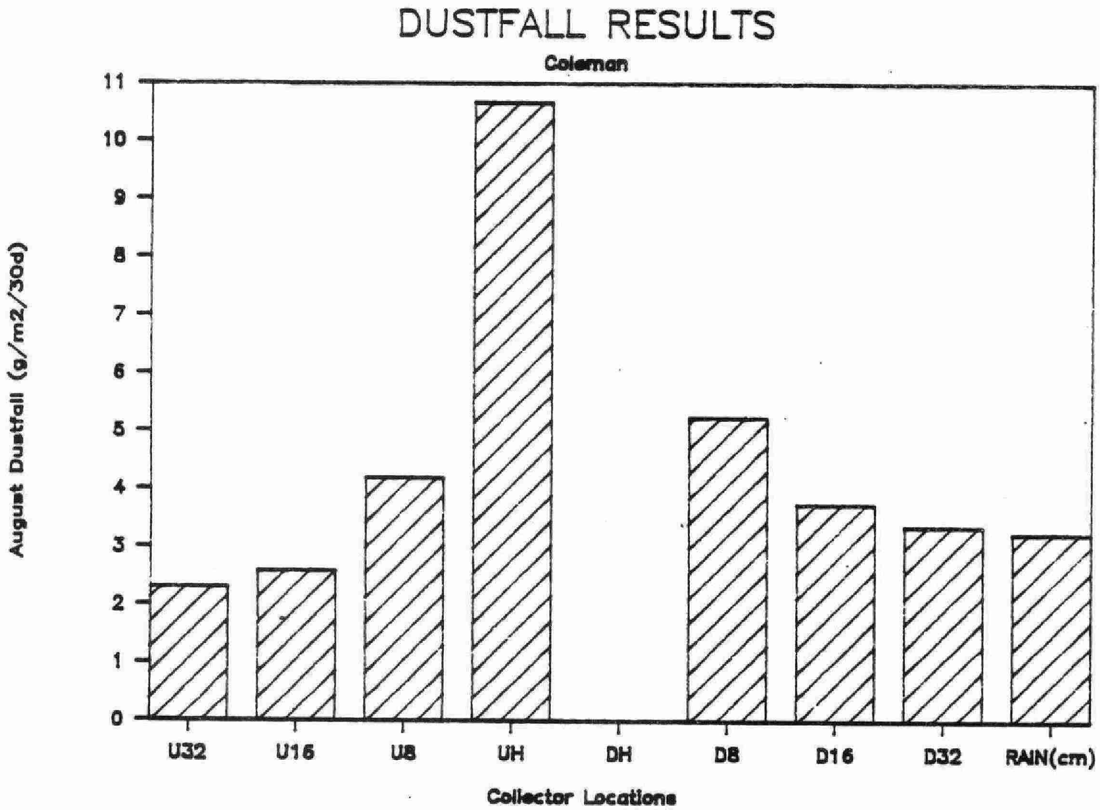


Fig. G 5b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - COLEMAN, AUGUST

ACRES

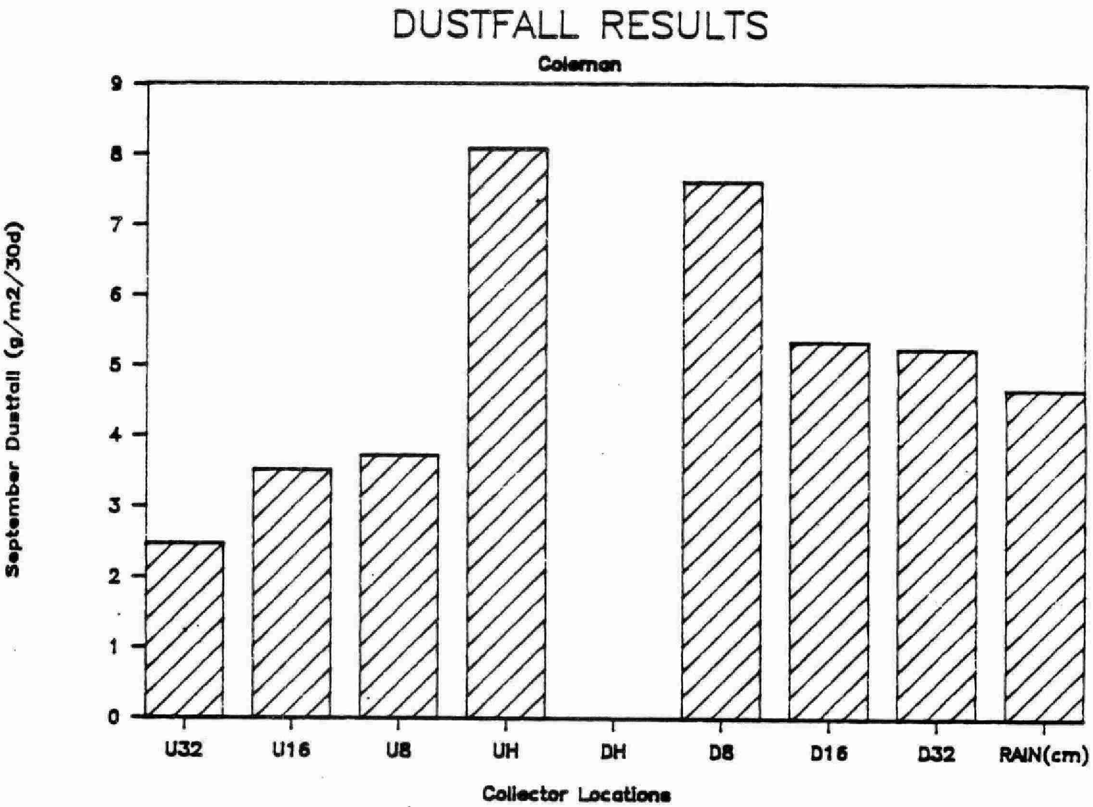


Fig. G 5c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - COLEMAN, SEPTEMBER

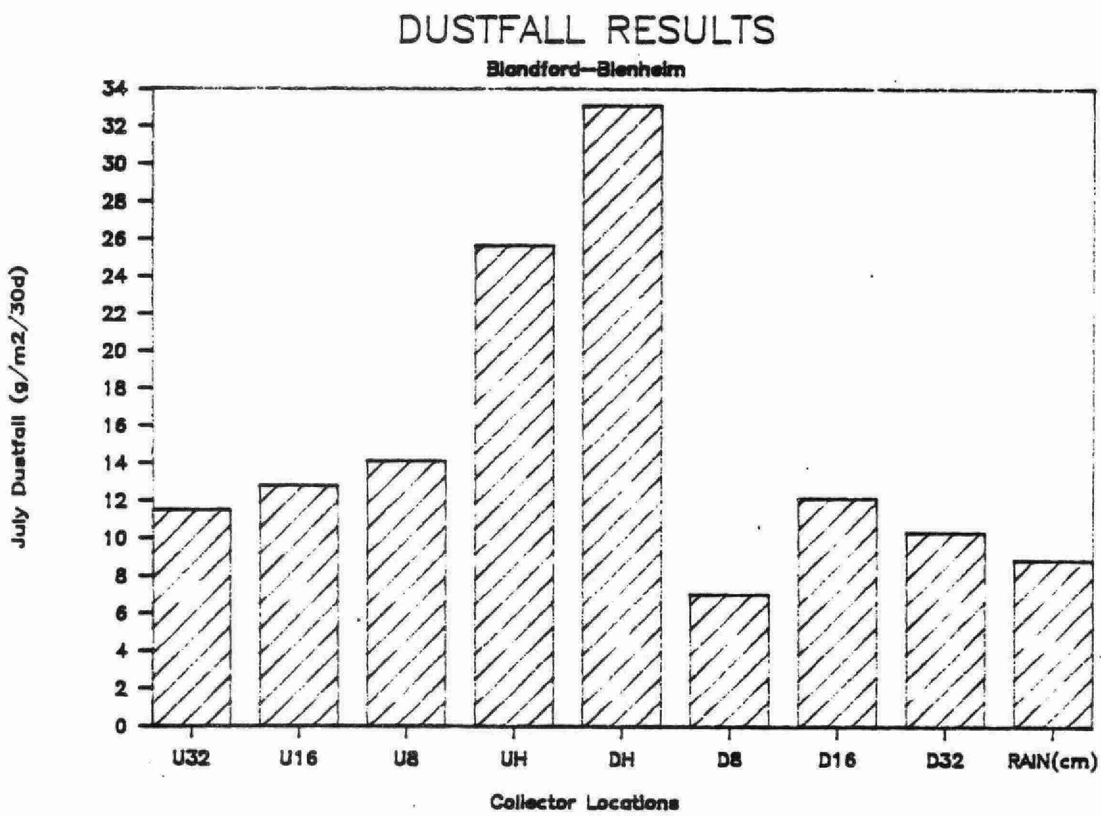


Fig. G 6a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - BLANDFORD BLENHEIM, JULY

ACRES

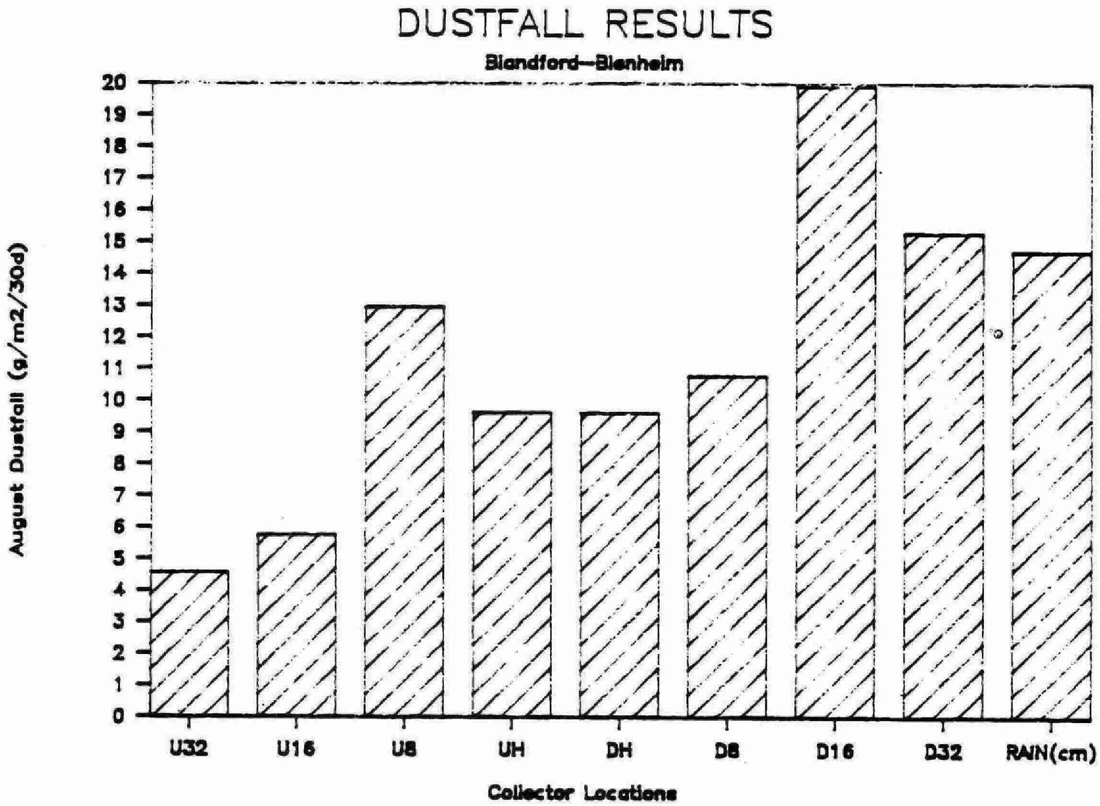


Fig. G 6b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - BLANDFORD BLENHEIM, AUGUST

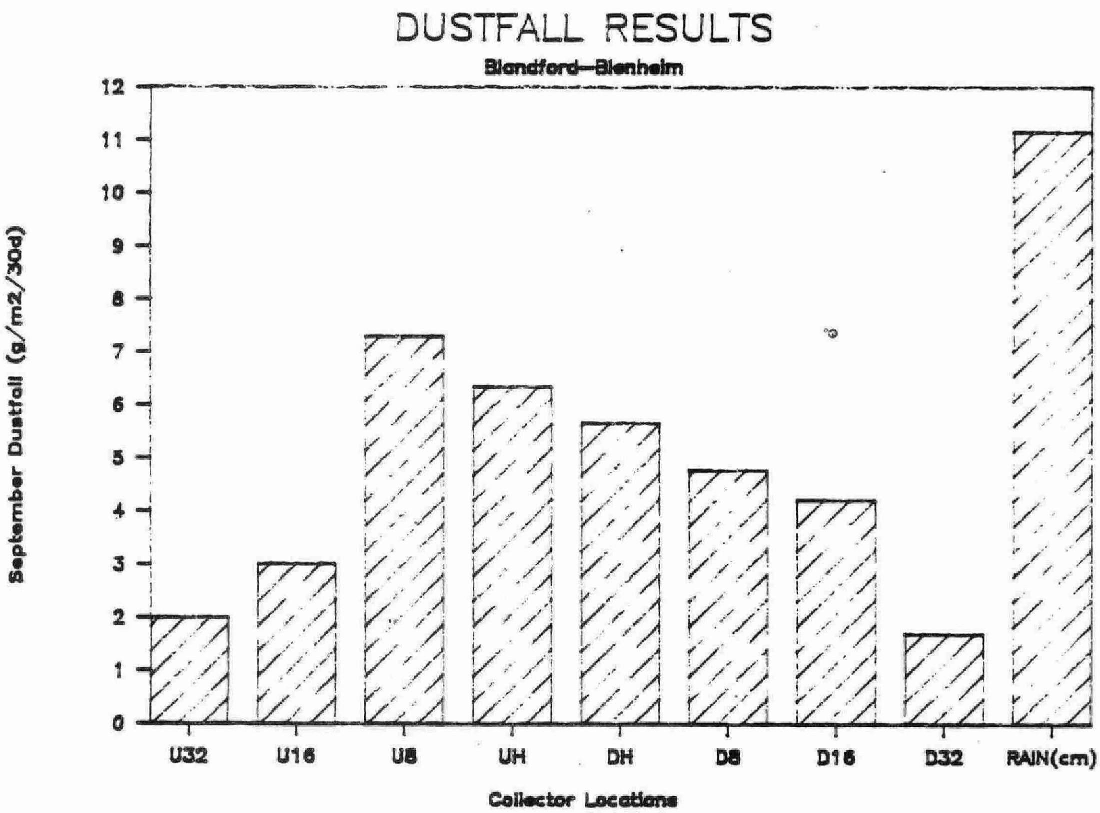


Fig. G 6c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

DUSTFALL RESULTS - BLANDFORD BLENHEIM, SEPTEMBER

APPENDIX H

RESULTS OF ENHANCED SAMPLING PROGRAM

APPENDIX H

LIST OF FIGURES

DUST SUPPRESSION TRAVERSAL RESULTS
JUNE 87 RUNS P8037.00

		Trial #	Sample Description	PARTICLE COUNT < 5.0 microns	PARTICLE COUNT 5-10 microns	PARTICLE COUNT >10.0 microns	PARTICLE AREA (u) < 5.0 microns	PARTICLE AREA (u) 5-10 microns	PARTICLE AREA (u) >10.0 microns	CONCENTRATION (ug/m3) < 5.0 microns	CONCENTRATION (ug/m3) 5-10 microns	CONCENTRATION (ug/m3) >10.0 microns	CONCENTRATION (ug/m3) TOTAL	HIVOL LOCATION	CONCENTRATION (ug/m3)
Location	NOIL	1	Roadside (E)	140	46	2	0.09	0.26	0.08	1.7	14.0	11.2	26.9	EAST	146.4
Date	JUNE 18/87		1m above road	1970	594	157	1.23	3.34	6.28	22.4	187.6	924.0	1134.0	WEST	116.2
Windspeed	5 knots		3m above road	196	25	0	0.13	0.14	0	2.5	8.4	0.0	10.9		
Wind Dir	NNW														
Humidity	51%	2	Roadside (E)	230	53	10	0.14	0.3	0.4	2.5	16.8	58.8	78.1		
Rating	3/10		1m above road	1220	194	39	0.76	1.09	1.56	14.0	61.6	232.4	308.0		
Moisture	2.0%		3m above road	206	42	9	0.13	0.24	0.36	2.5	14.0	53.2	69.7		
Location	MILTON	1	Roadside (E)	359	78	5	0.22	0.44	0.2	5.6	25.2	30.8	61.6	EAST	147.2
Date	JUNE 19/87		1m above road	329	61	18	0.21	0.34	0.72	2.8	19.6	106.4	128.8	WEST	104.5
Windspeed	4 knots		3m above road	358	116	19	0.22	0.65	0.7	5.6	36.4	103.6	145.6		
Wind Dir	NW														
Humidity	57%	2	Roadside (E)	802	250	64	0.5	1.41	2.56	8.4	78.4	392.0	478.8		
Rating	9/10		1m above road	3284	963	388	2.05	5.42	15.52	39.2	308.0	2296.0	2643.2		
Moisture	6.0%		3m above road	156	59	8	0.1	0.33	0.32	2.0	19.6	47.6	69.2		
Location	HALLOWELL	1	Roadside (E)	331	66	8	0.21	0.37	0.32	2.8	19.6	47.6	70.0	EAST	218.6
Date	JUNE 20/87		1m above road	13406	4381	1094	8.38	24.64	43.76	156.8	1372.0	6440.1	7968.9	WEST	72.5
Windspeed	3 knots		3m above road	478	58	4	0.3	0.33	0.16	5.6	19.6	25.2	50.4		
Wind Dir	NW														
Humidity	54%	2	Roadside (E)	449	35	5	0.28	0.2	0.2	5.6	11.2	30.8	47.6		
Rating	6/10		1m above road	13962	3622	881	8.73	20.37	35.24	162.4	1148.0	5320.0	6630.5		
Moisture	1.0%		3m above road	504	65	6	0.32	0.37	0.24	5.6	19.6	36.4	61.6		
Location	COLEMAN	1	Roadside (E)	1158	162	20	0.72	0.91	0.8	14.0	50.4	117.6	182.0	EAST	481.1
Date	JUNE 24/87		1m above road	33883	10563	3871	21.2	59.42	154.84	392.0	3360.0	22960.2	26712.2	WEST	71.9
Windspeed	0-5 knots		3m above road	1447	98	6	0.9	0.55	0.24	16.8	30.8	36.4	84.0		
Wind Dir	W														
Humidity	86%	2	Roadside (E)	784	95	11	0.49	0.53	0.44	8.4	30.8	64.4	103.6		
Rating	5/10		1m above road	84590	7693	3185	52.9	43.27	127.4	980.0	2408.0	19040.2	22428.2		
Moisture	2.4%		3m above road	1212	86	7	0.76	0.48	0.28	14.0	28.0	42.0	84.0		
Location	ARMOUR	1	Roadside (N)	640	156	16	0.4	0.88	0.64	8.4	47.6	95.2	151.2	NORTH	65.5
Date	JUNE 25/87		1m above road	1968	219	34	1.23	1.23	1.36	22.4	70.0	201.6	294.0	SOUTH	60.1
Windspeed	5 knots		3m above road	735	96	24	0.46	0.54	0.96	8.4	30.8	142.8	182.0		
Wind Dir	SW														
Humidity	68%	2	Roadside (N)	439	90	24	0.27	0.51	0.96	5.6	28.0	142.8	176.4		
Rating	8/10		1m above road	1049	121	29	0.66	0.68	1.16	11.2	39.2	173.6	224.0		
Moisture	2.0%		3m above road	1051	46	2	0.66	0.26	0.08	11.2	14.0	11.2	36.4		
Location	BLANDFORD	1	Roadside (N)	1390	50	6	0.87	0.28	0.24	16.8	16.8	36.4	70.0	NORTH	232.1
Date	JUNE 30/87		1m above road	14984	3505	850	9.37	19.7	34	173.6	1092.0	5040.0	6305.7	SOUTH	150.8
Windspeed	L&V		3m above road	791	141	18	0.49	0.79	0.72	8.4	44.8	106.4	159.6		
Wind Dir	SW														
Humidity	68%	2	Roadside (N)	674	82	18	0.42	0.46	0.72	8.4	25.2	106.4	140.0		
Rating	2/10		1m above road	10645	2214	556	6.65	12.45	22.24	123.2	700.0	3360.0	4183.2		
Moisture	3.0%		3m above road	509	125	8	0.32	0.7	0.32	5.6	39.2	47.6	92.4		

DUST SUPPRESSION TRAVERSAL RESULTS
JULY 87 RUNS PB037.00

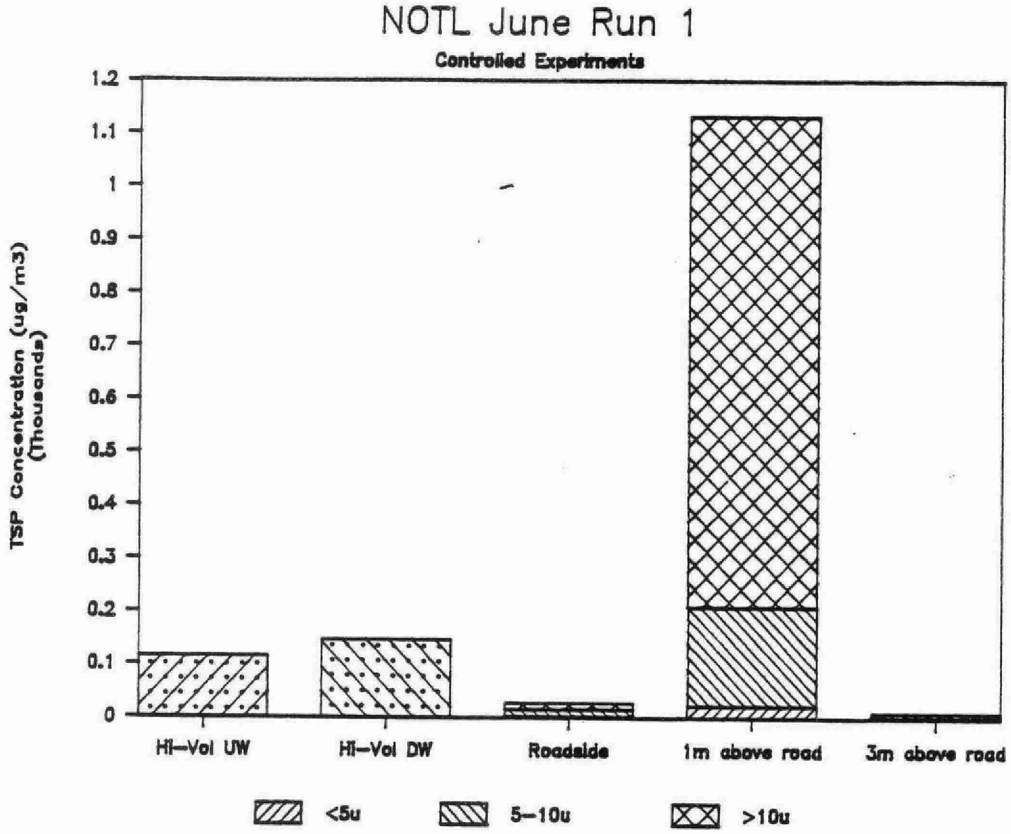
		Trial #	Sample Description	PARTICLE COUNT < 5.0 microns	5-10 microns	>10.0 microns	PARTICLE AREA (u) < 5.0 microns	5-10 microns	>10.0 microns	CONCENTRATION (ug/m3) < 5.0 microns	5-10 microns	>10.0 microns	TOTAL	HIVOL LOCATION	CONCENTRATION (ug/m3)
Location	NOTL	1	Roadside (E)	608	56	12	0.28	0.27	0.48	4.1	10.2	50.9	65.2	EAST	70.8
Date	JULY 21/87		1m above road	1243	272	33	0.5	1.32	1.32	6.2	51.9	145.2	203.3	WEST	39.0
Windspeed	0-5 knots		3m above road	347	40	4	0.14	0.2	0.16	1.6	9.2	20.7	31.6		
Wind Dir	NW														
Humidity	62%	2	Roadside (E)	593	90	24	0.24	0.44	0.96	1.9	15.2	97.1	114.3		
Rating	8/10		1m above road	885	149	31	0.35	0.73	1.24	3.3	23.3	110.0	136.7		
Moisture	3.0%		3m above road	510	82	8	0.2	0.4	0.32	1.8	12.4	30.2	44.4		
Location	MILTON	1	Roadside (E)	443	43	8	0.18	0.21	0.32	1.8	7.1	30.2	39.1	EAST	61.2
Date	JULY 22/87		1m above road	884	212	57	0.35	1.04	2.28	3.6	33.8	213.3	250.7	WEST	34.7
Windspeed	3 knots		3m above road	374	52	10	0.15	0.26	0.4	1.4	8.9	37.3	47.6		
Wind Dir	NE														
Humidity	72%	2	Roadside (E)	1164	300	61	0.47	1.47	2.44	5.4	48.8	234.8	289.0		
Rating	9/10		1m above road	935	153	44	0.37	0.75	1.76	3.7	26.1	173.6	203.5		
Moisture	3.0%		3m above road	589	85	23	0.24	0.42	0.92	1.9	14.9	91.5	108.3		
Location	HALLOWELL	1	Roadside (W)	344	97	29	0.14	0.48	1.16	1.2	14.8	102.1	118.1	EAST	137.0
Date	JULY 19/87		1m above road	250	82	26	0.1	0.4	1.04	0.8	11.5	90.6	102.9	WEST	372.8
Windspeed	0-4 knots		3m above road	190	123	41	0.08	0.6	1.64	0.6	1.5	131.7	133.8		
Wind Dir	SE														
Humidity	53%	2	Roadside (W)	-	-	-	-	-	-				0.0		
Rating	6/10		1m above road	120	59	25	0.05	0.29	1	0.6	10.0	106.4	117.0		
Moisture	0.2%		3m above road	172	118	37	0.07	0.58	1.48	0.7	20.1	142.7	163.6		
Location	COLEMAN	1	Roadside (W)	433	91	14	0.17	0.45	0.56	1.3	11.2	42.1	54.6	EAST	75.1
Date	JULY 25/87		1m above road	455	67	23	0.18	0.33	0.92	1.6	9.3	76.2	87.1	WEST	114.0
Windspeed	0-5 knots		3m above road	382	67	17	0.15	0.33	0.68	1.5	11.6	69.5	82.6		
Wind Dir	NE														
Humidity	60%	2	Roadside (W)	313	81	20	0.13	0.4	0.8	1.3	12.6	75.9	89.8		
Rating	6/10		1m above road	142	46	18	0.06	0.23	0.72	0.6	8.3	78.8	87.7		
Moisture	4.0%		3m above road	120	49	11	0.05	0.24	0.44	0.6	9.7	44.4	54.6		
Location	ARMOUR	1	Roadside (S)	268	57	9	0.11	0.28	0.36	0.9	7.3	27.7	35.9	NORTH	83.7
Date	JULY 26/87		1m above road	174	52	18	0.07	0.26	0.72	0.6	7.4	56.1	64.0	SOUTH	90.4
Windspeed	2-6 knots		3m above road	278	61	16	0.11	0.3	0.64	0.9	9.1	51.7	61.8		
Wind Dir	NNW														
Humidity	59%	2	Roadside (S)	297	67	16	0.12	0.33	0.64	0.9	8.7	49.5	59.1		
Rating	8/10		1m above road	413	115	34	0.17	0.56	1.36	1.4	15.7	112.9	130.0		
Moisture	1.3%		3m above road	357	131	32	0.14	0.64	1.28	1.0	16.4	93.0	110.4		
Location	BLANDFORD	1	Roadside (E)	1039	190	47	0.42	0.93	1.88	4.4	37.8	222.2	264.4	NORTH	1241.5
Date	JULY 23/87		1m above road	10729	3228	697	4.29	15.8	27.9	53.3	681.7	3478.3	4213.4	SOUTH	772.7
Windspeed	4-7 knots		3m above road	1295	484	81	0.52	0.24	3.24	7.0	11.6	394.2	412.8		
Wind Dir	SW														
Humidity	54%	2	Roadside (E)	1310	187	41	0.52	0.92	1.68	6.4	36.1	188.8	231.2		
Rating	2/10		1m above road	35060	13229	2941	14	64.8	117.6	139.5	2281.5	11690.3	14111.4		
Moisture	2.0%		3m above road	2982	437	83	1.19	2.14	3.32	11.3	75.4	339.4	426.1		

DUST SUPPRESSION TRAVERSAL RESULTS
AUGUST 87 RUNS PB037.00

		Trial #	Sample Description	PARTICLE COUNT < 5.0 microns	PARTICLE COUNT 5-10 microns	PARTICLE COUNT >10.0 microns	PARTICLE AREA (u) < 5.0 microns	PARTICLE AREA (u) 5-10 microns	PARTICLE AREA (u) >10.0 microns	CONCENTRATION (ug/m3) < 5.0 microns	CONCENTRATION (ug/m3) 5-10 microns	CONCENTRATION (ug/m3) >10.0 microns	CONCENTRATION (ug/m3) TOTAL	HIVOL LOCATION	CONCENTRA (ug/m3)
Location	MOTL	1	Roadside (E)	492	84	14	0.31	0.47	0.56	3.6	16.3	54.2	74.1	EAST	363.6
Date	AUG 24/87		1m above road	10980	1531	188	6.86	8.61	7.52	78.1	290.2	677.1	1045.3	WEST	32.7
Windspeed	0-5 knots		3m above road	885	54	7	0.55	0.3	0.28	7.7	11.6	29.0	48.3		
Wind Dir	W														
Humidity	64%	2	Roadside (E)	394	39	3	0.25	0.22	0.12	3.9	7.7	11.6	23.2		
Rating	4/10		1m above road	10057	1648	245	6.29	9.27	9.8	84.0	368.0	1038.0	1490.0		
Moisture	1%		3m above road	459	59	8	0.29	0.33	0.32	3.4	11.9	28.8	44.1		
Location	MILTON	1	Roadside (E)	395	39	3	0.25	0.22	0.12	3.6	7.2	10.8	21.7	EAST	20.7
Date	SEPT 1/87		1m above road	649	62	8	0.41	0.35	0.32	4.8	11.2	27.2	43.2	WEST	39.5
Windspeed	1-4 knots		3m above road	338	33	2	0.21	0.19	0.08	2.1	8.3	8.3	18.7		
Wind Dir	NW														
Humidity	76%	2	Roadside (E)	315	34	2	0.2	0.19	0.08	1.9	7.7	7.7	17.4		
Rating	9/10		1m above road	690	72	14	0.43	0.41	0.56	5.1	13.6	50.9	69.6		
Moisture	3%		3m above road	493	65	15	0.31	0.37	0.6	3.7	13.1	59.7	76.5		
Location	HALLOWELL	1	Roadside (E)	1014	190	38	0.63	1.07	1.52	6.2	32.7	126.0	164.9	EAST	244.9
Date	AUG 30/87		1m above road	23924	4211	974	14.95	23.69	38.96	163.1	775.8	3401.2	4340.0	WEST	32.2
Windspeed	2-7 knots		3m above road	714	65	12	0.45	0.37	0.48	4.8	11.2	40.0	56.0		
Wind Dir	SW														
Humidity	76%	2	Roadside (E)	1328	165	29	0.83	0.93	1.16	10.5	33.3	108.5	152.3		
Rating	8/10		1m above road	28683	4607	493	17.93	25.91	19.72	201.9	873.9	1773.3	2849.2		
Moisture	2%		3m above road	1063	70	11	0.66	0.39	0.44	6.8	13.6	39.0	59.4		
Location	COLEMAN	1	Roadside (E)	2503	324	39	1.56	1.82	1.56	14.7	53.1	122.3	190.1	EAST	434.1
Date	AUG 27/87		1m above road	39731	7390	1407	24.83	41.57	56.78	308.0	1541.9	5568.3	7418.2	WEST	374.9
Windspeed	0-3 knots		3m above road	1236	107	12	0.77	0.6	0.48	8.0	19.2	40.0	67.2		
Wind Dir	SW - SE														
Humidity	66%	2	Roadside (W)	2326	333	33	1.45	1.87	1.32	16.0	59.2	112.0	187.2		
Rating	4/10		1m above road	41869	8236	1710	26.17	46.33	68.4	284.9	1517.0	5970.6	7772.5		
Moisture	1%		3m above road	1682	209	33	1.05	1.18	1.32	112.0	36.8	112.0	260.8		
Location	ARMOUR	1	Roadside (N)	209	10	3	0.13	0.06	0.12	1.8	1.8	10.8	14.5	NORTH	36.1
Date	AUG 26/87		1m above road	150	21	9	0.09	0.12	0.36	1.9	3.9	36.7	42.5	SOUTH	134.4
Windspeed	0-2 knots		3m above road	313	53	6	0.2	0.3	0.24	1.8	10.8	23.5	36.1		
Wind Dir	N														
Humidity	54%	2	Roadside (N)	649	50	4	0.41	0.28	0.16	5.4	10.8	16.3	32.5		
Rating	8/10		1m above road	813	111	22	0.51	0.62	0.88	4.4	17.7	69.3	91.4		
Moisture	2%		3m above road	454	42	7	0.28	0.24	0.28	3.6	9.0	27.1	39.7		
Location	BLANDFORD	1	Roadside (N)	993	198	66	0.62	1.11	2.64	6.6	36.2	230.6	273.4	NORTH	256.9
Date	AUG 25/87		1m above road	26741	5600	1436	16.71	31.5	57.44	155.4	876.4	4261.6	5293.4	SOUTH	949.0
Windspeed	0-3 knots		3m above road	652	135	24	0.41	0.76	0.96	4.9	24.7	84.0	113.6		
Wind Dir	NW														
Humidity	54%	2	Roadside (S)	1975	209	11	1.23	1.18	0.41	11.5	33.0	33.0	77.5		
Rating	2/10		1m above road	25796	1189	2917	10.12	6.69	116.7	199.7	248.3	11543.6	11991.6		
Moisture	2%		3m above road	2339	294	44	1.46	1.65	1.76	15.6	51.3	144.7	211.6		

DUST SUPPRESSION TRAVERSAL RESULTS
SEPTEMBER 87 RUNS P8037.00

		Trial #	Sample Description	PARTICLE COUNT < 5.0 microns	PARTICLE COUNT 5-10 microns	PARTICLE COUNT >10.0 microns	PARTICLE AREA (u) < 5.0 microns	PARTICLE AREA (u) 5-10 microns	PARTICLE AREA (u) >10.0 microns	CONCENTRATION (ug/m3) < 5.0 microns	CONCENTRATION (ug/m3) 5-10 microns	CONCENTRATION (ug/m3) >10.0 microns	TOTAL	HIVOL LOCATION	CONCENTRATION (ug/m3)
Location	NOTL	1	Roadside (E)	422	52	8	0.26	0.29	0.32	3.9	11.7	33.1	48.6	EAST	207.4
Date	OCT 14/87		1m above road	1650	459	105	1.03	2.58	4.2	14.1	102.4	447.6	564.0	WEST	90.4
Windspeed	5-10 knots		3m above road	352	39	11	0.22	0.22	0.44	3.7	7.3	42.1	53.1		
Wind Dir	SSW														
Humidity	60%	2	Roadside (E)	644	55	13	0.4	0.31	0.52	6.2	12.4	58.1	76.7		
Rating	4/10		1m above road	1733	596	102	1.08	3.75	4.08	12.8	122.6	395.3	530.7		
Moisture	3%		3m above road	553	54	15	0.35	0.3	0.6	3.7	11.0	58.6	73.2		
Location	MILTON	1	Roadside (E)	830	104	24	0.52	0.59	0.96	5.2	20.8	88.4	114.4	EAST	201.1
Date	OCT 6/87		1m above road	1532	486	108	0.96	2.73	4.32	10.7	96.0	407.1	513.8	WEST	67.7
Windspeed	5-10 knots		3m above road	480	84	20	0.3	0.47	0.8	3.9	17.5	81.7	103.1		
Wind Dir	WSW - W														
Humidity	91%	2	Roadside (E)	505	67	19	0.32	0.38	0.76	3.6	14.3	71.5	89.3		
Rating	8/10		1m above road	1259	326	45	0.79	1.83	1.8	8.9	65.8	168.9	243.6		
Moisture	4%		3m above road	555	64	16	0.35	0.36	0.64	3.7	12.8	62.2	78.7		
Location	HALLOWELL	1	Roadside (E)	2538	691	61	1.59	3.89	2.44	17.6	123.2	206.4	347.2	EAST	400.0
Date	SEPT 28/87		1m above road	19964	4776	587	12.49	26.87	26.48	125.6	808.2	1882.8	2816.7	WEST	222.7
Windspeed	5 knots		3m above road	714	50	4	0.45	0.28	0.16	4.7	9.3	14.0	28.0		
Wind Dir	SSW														
Humidity	57%	2	Roadside (E)	2589	513	50	1.62	2.89	2	17.1	88.7	164.9	270.7		
Rating	4/10		1m above road	34270	4973	1933	21.42	67.35	77.32	233.9	2205.4	6749.7	9189.0		
Moisture	6%		3m above road	761	157	42	0.48	0.88	1.68	4.8	28.8	142.4	176.0		
Location	COLEMAN	1	Roadside (E)	2503	505	61	3	0.32	0.34	3.7	13.1	11.2	28.0	EAST	34.8
Date	OCT 2/87		1m above road	1051	208	57	0.66	1.17	2.28	6.9	39.9	209.8	256.6	WEST	26.9
Windspeed	10 knots		3m above road	309	27	20	0.19	0.15	0.8	2.0	6.1	85.4	93.5		
Wind Dir	SSW														
Humidity	63%	2	Roadside (E)	620	30	8	0.39	0.17	0.32	4.9	4.9	28.0	37.9		
Rating	8.5/10		1m above road	5130	1385	460	3.21	7.79	18.4	35.6	263.0	1654.6	1953.2		
Moisture	6%		3m above road	580	111	11	0.36	0.62	0.44	3.7	22.4	42.9	69.1		
Location	ARMOUR	1	Roadside (N)	550	17	3	0.34	0.01	0.12	3.6	3.6	10.8	18.1	NORTH	183.3
Date	OCT 1/87		1m above road	1850	285	76	1.16	1.6	3.04	12.1	48.4	243.7	304.2	SOUTH	72.8
Windspeed	calm to 10 knots		3m above road	313	327	11	3	0.2	0.06	1.8	1.8	10.8	14.5		
Wind Dir	SSW														
Humidity	50%	2	Roadside (N)	943	60	6	0.59	0.34	0.24	7.0	12.3	22.8	42.0		
Rating	7/10		1m above road	1060	109	36	0.66	0.61	1.44	6.6	19.8	125.2	151.5		
Moisture	2.5%		3m above road	293	15	2	0.18	0.08	0.08	1.7	3.4	6.8	11.9		
Location	BLANDFORD	1	Roadside (N)	666	80	33	0.42	0.45	1.32	4.8	14.4	112.0	131.2	NORTH	259.0
Date	OCT 5/87		1m above road	68163	15361	2521	42.6	86.41	100.84	493.5	3004.8	9353.8	12852.1	SOUTH	98.3
Windspeed	SSW		3m above road	165	32	7	0.1	0.18	0.28	1.7	6.8	25.5	33.9		
Wind Dir	8 to 14 knots														
Humidity	50%	2	Roadside (N)	792	76	15	0.5	0.43	0.6	4.6	13.7	48.8	67.0		
Rating	2/10		1m above road	93551	23722	6054	58.47	133.44	242.16	589.7	4041.2	19556.8	24187.7		
Moisture	2.5%		3m above road	704	69	20	0.44	0.39	0.8	4.7	12.5	65.9	83.1		



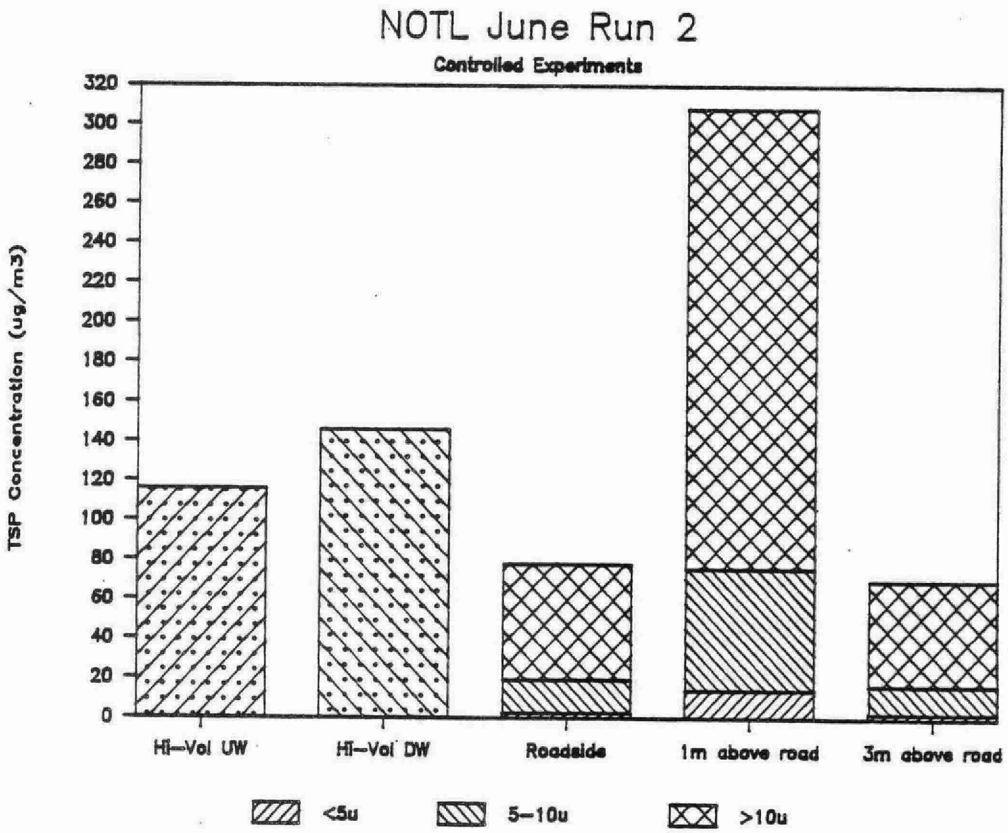
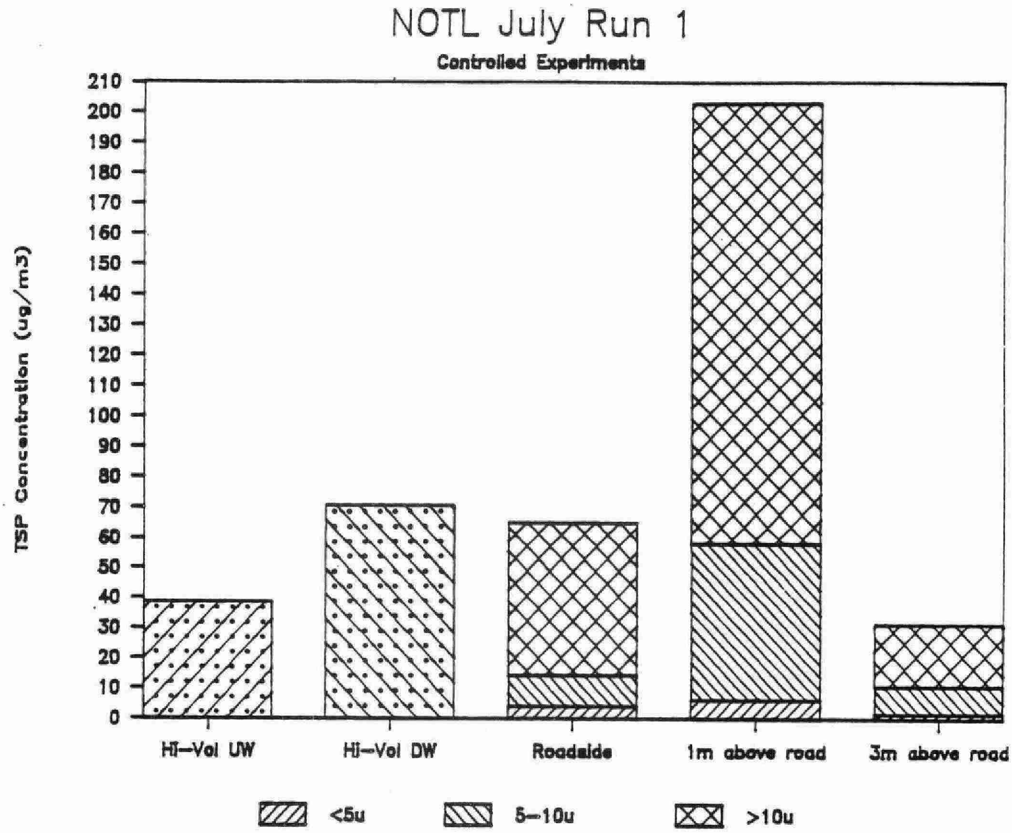


Fig. H 1a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - NIAGARA ON THE LAKE, JUNE

ACRES



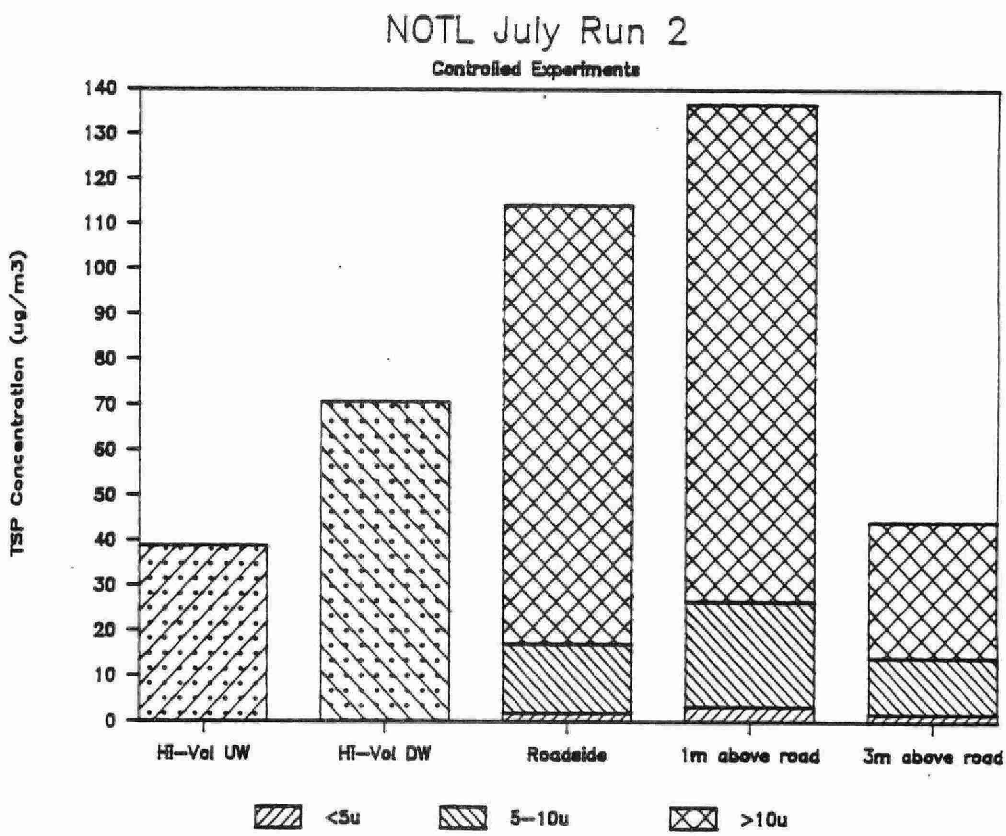
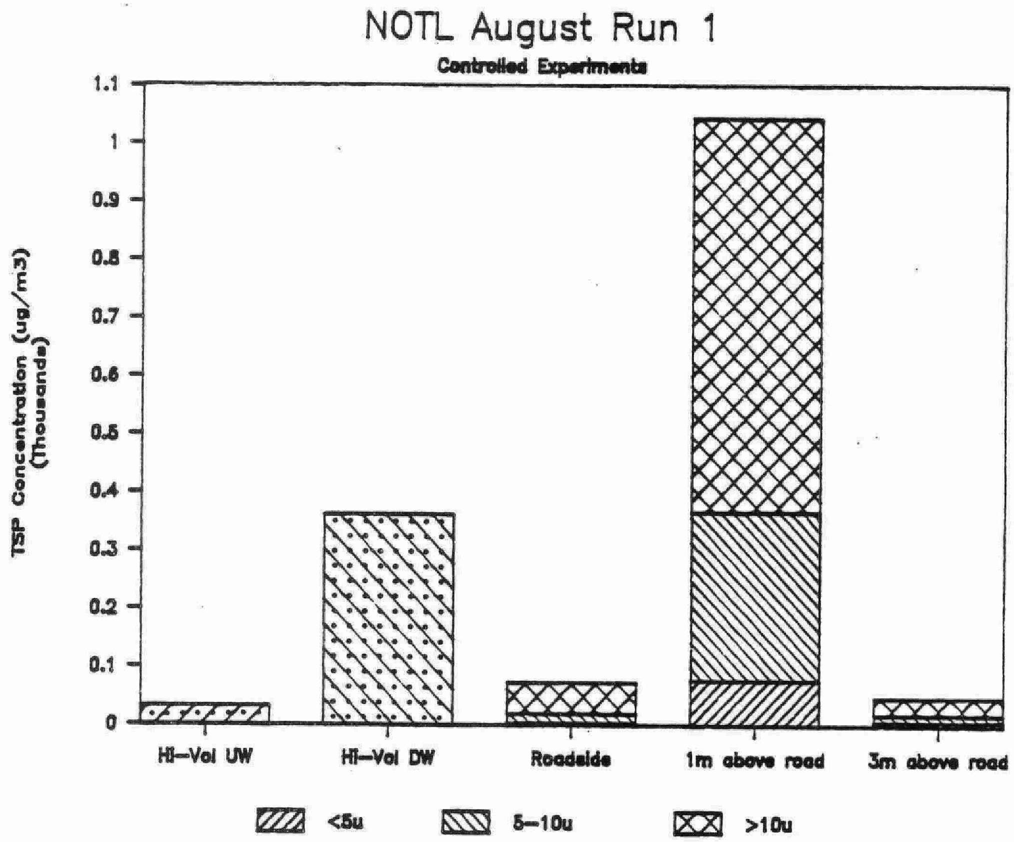


Fig. H 1b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - NIAGARA ON THE LAKE, JULY

ACRES



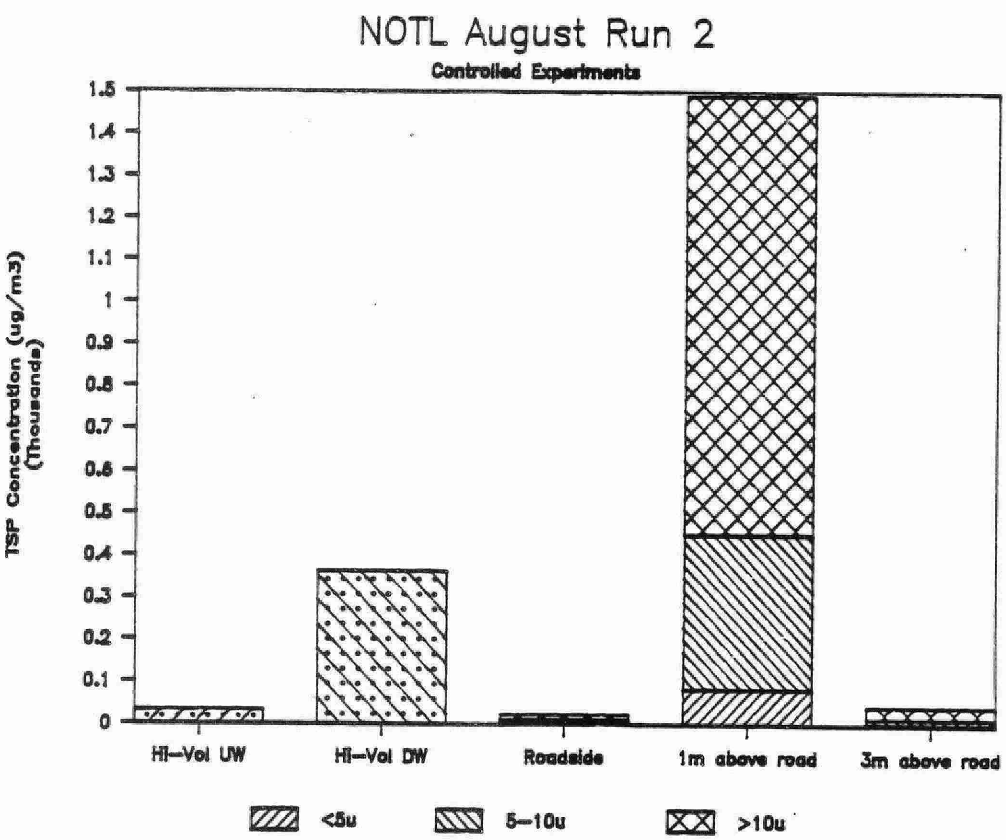
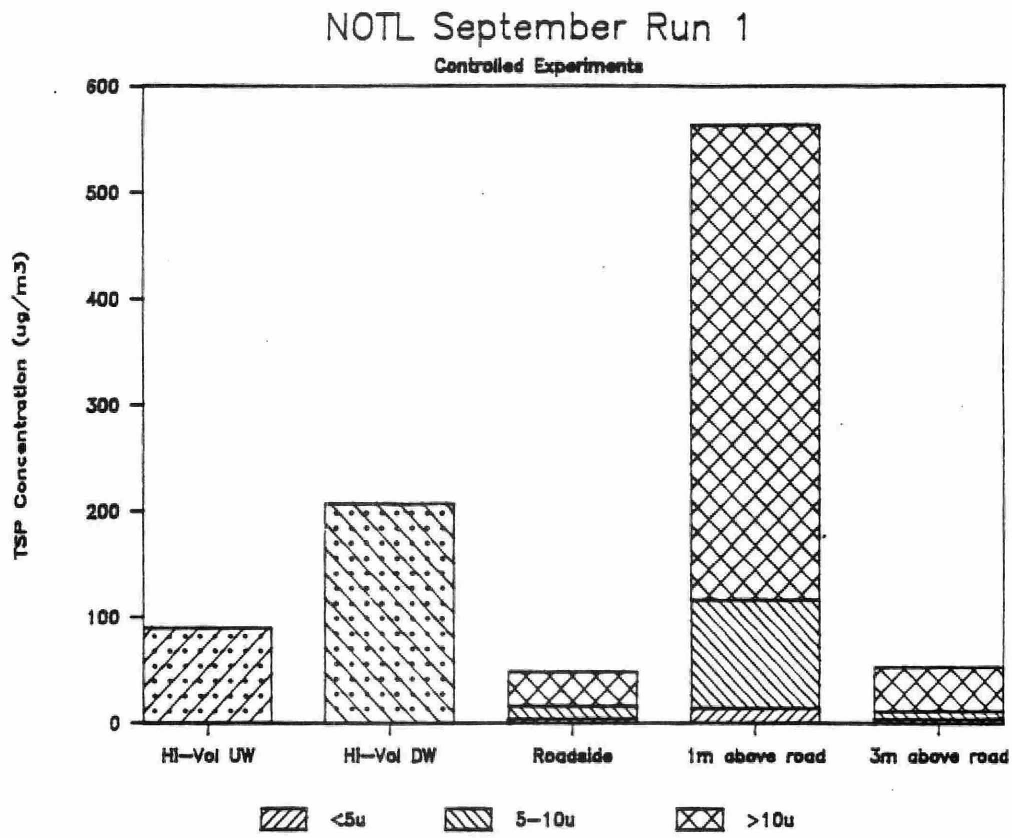


Fig. H 1c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - NIAGARA ON THE LAKE, AUGUST

ACRES



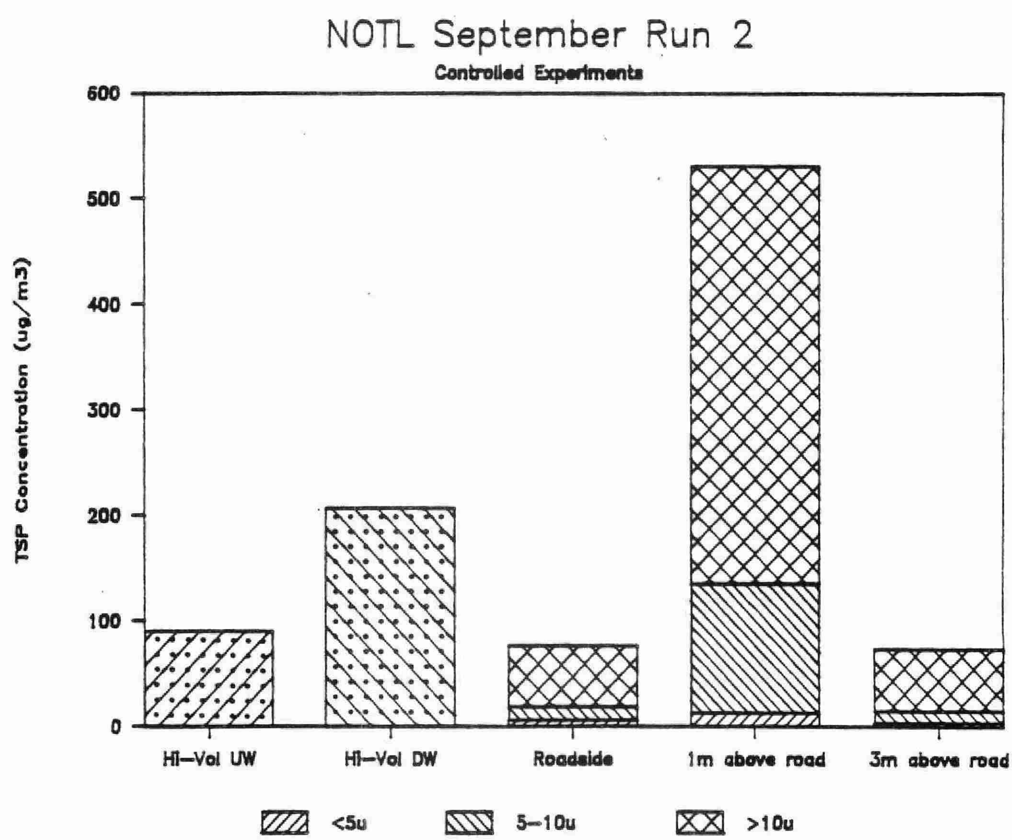
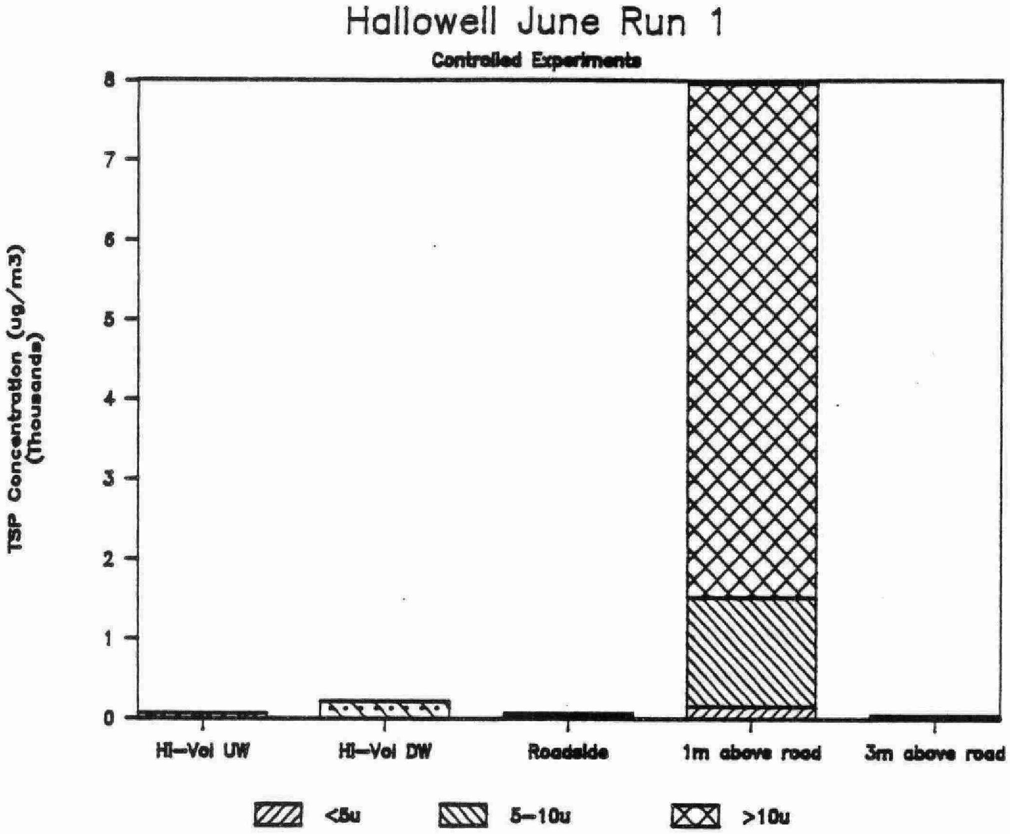


Fig. H 1d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - NIAGARA ON THE LAKE, SEPTEMBER

ACRES



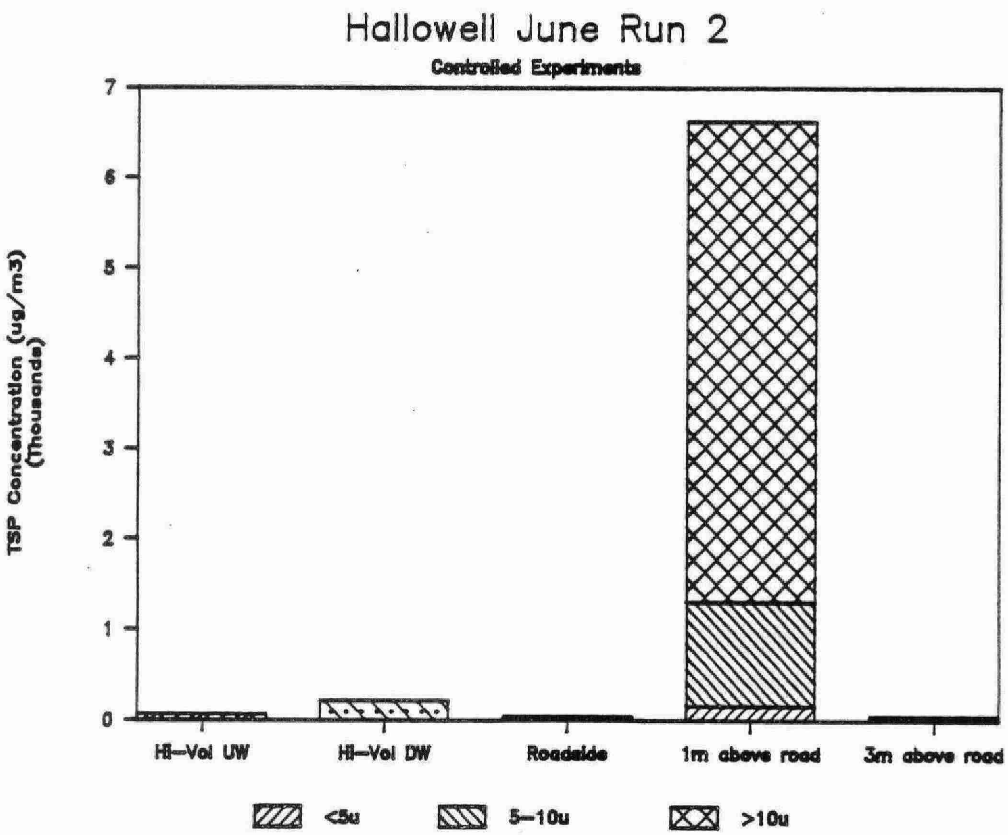
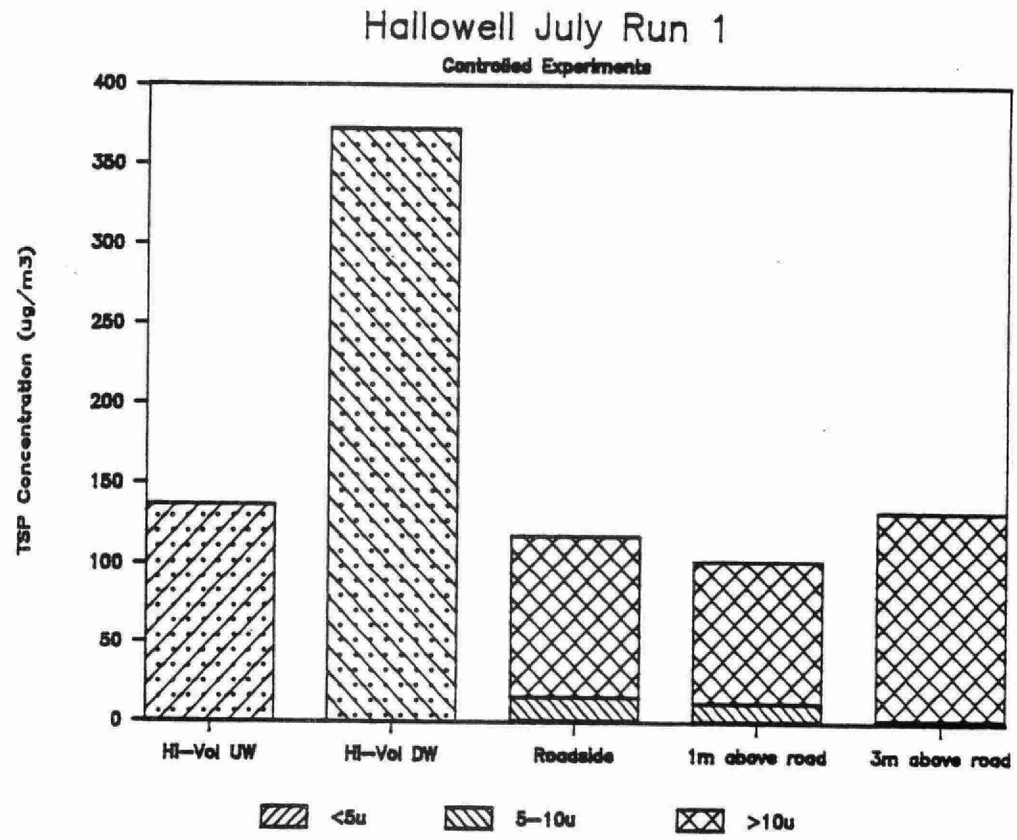


Fig. H 2a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - HALLOWELL, JUNE

ACRES



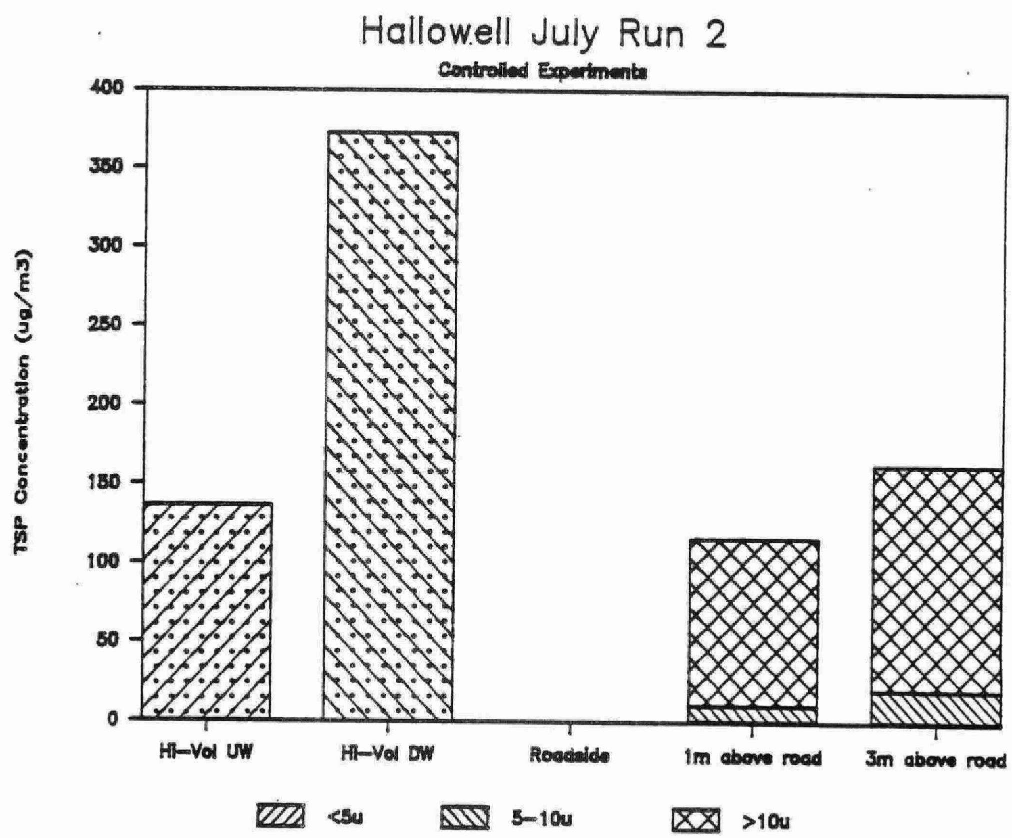
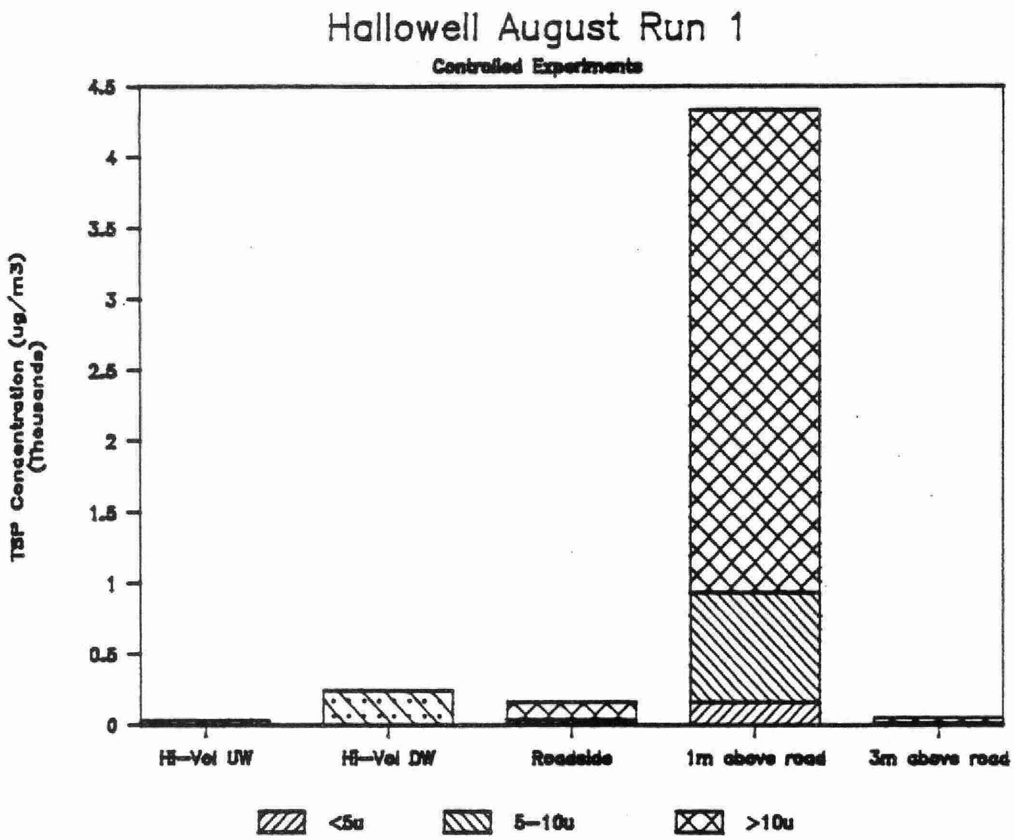


Fig. H 2b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - HALLOWELL, JULY

ACRES



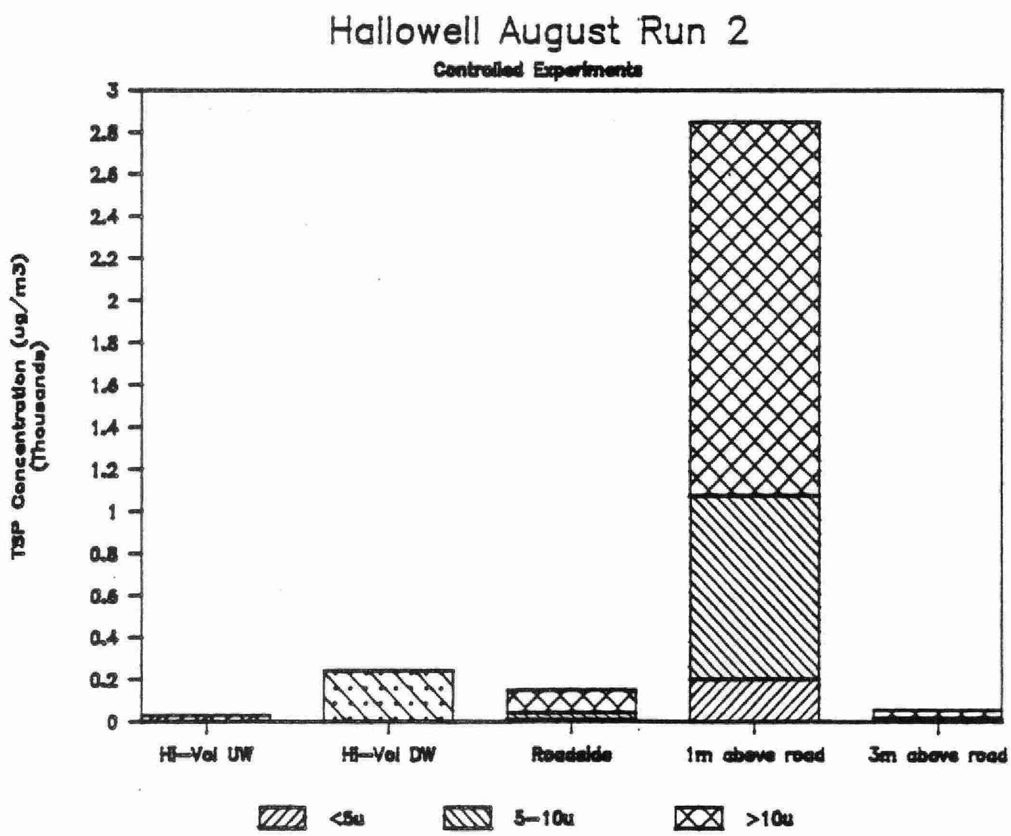
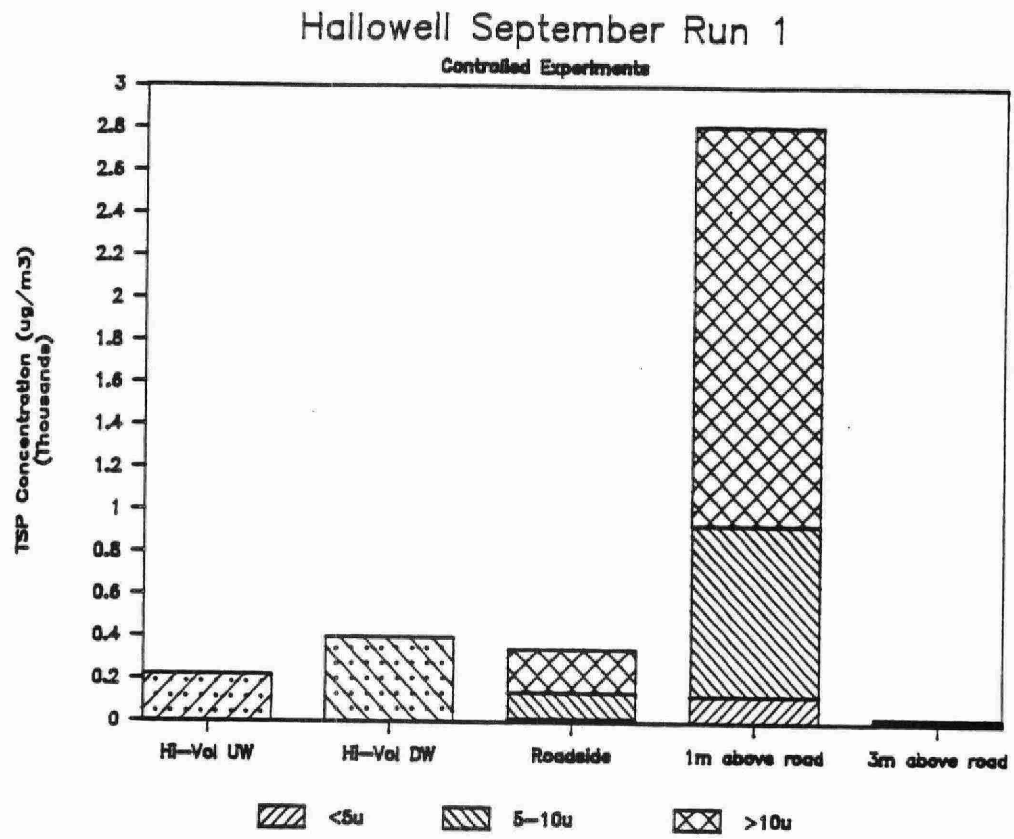


Fig. H 2c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - HALLOWELL, AUGUST

ACRES



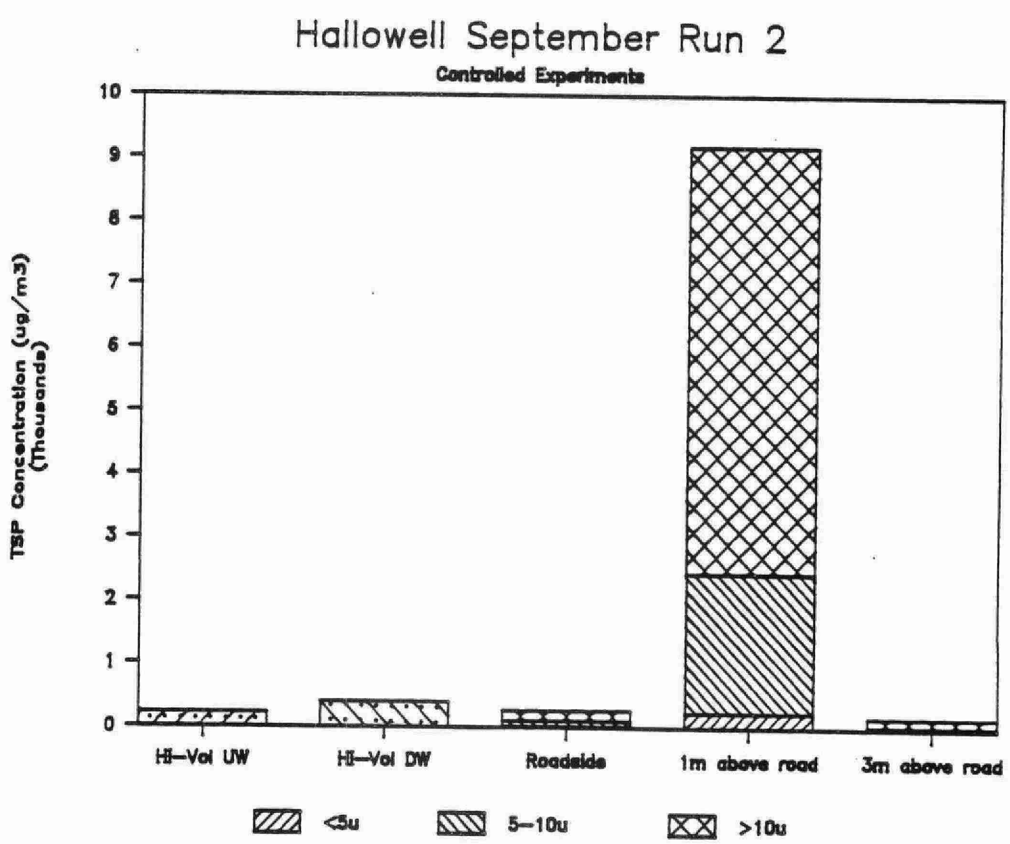
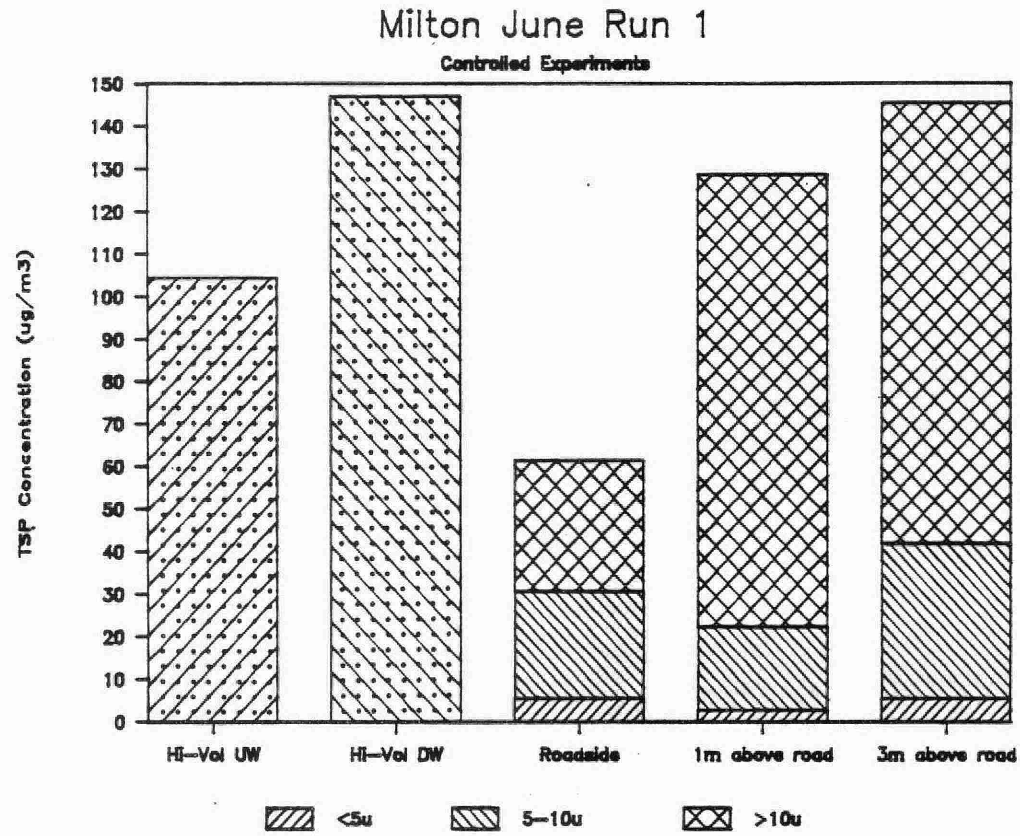


Fig. H 2d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - HALLOWELL, SEPTEMBER

ACRES



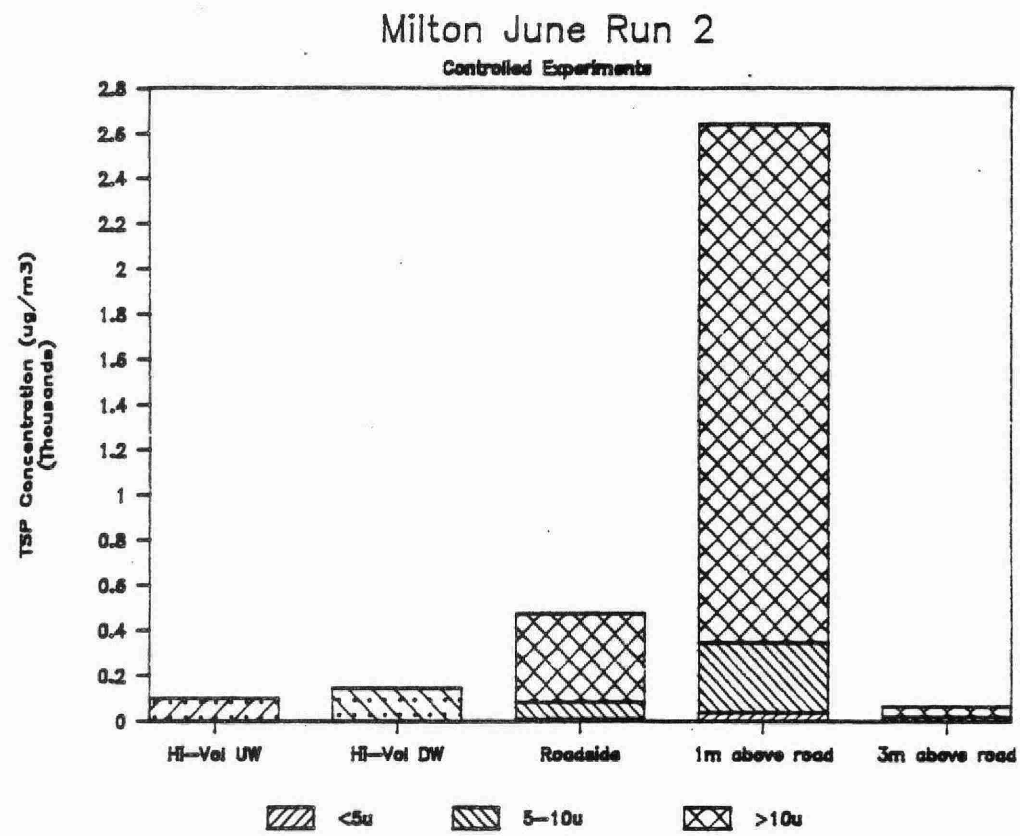
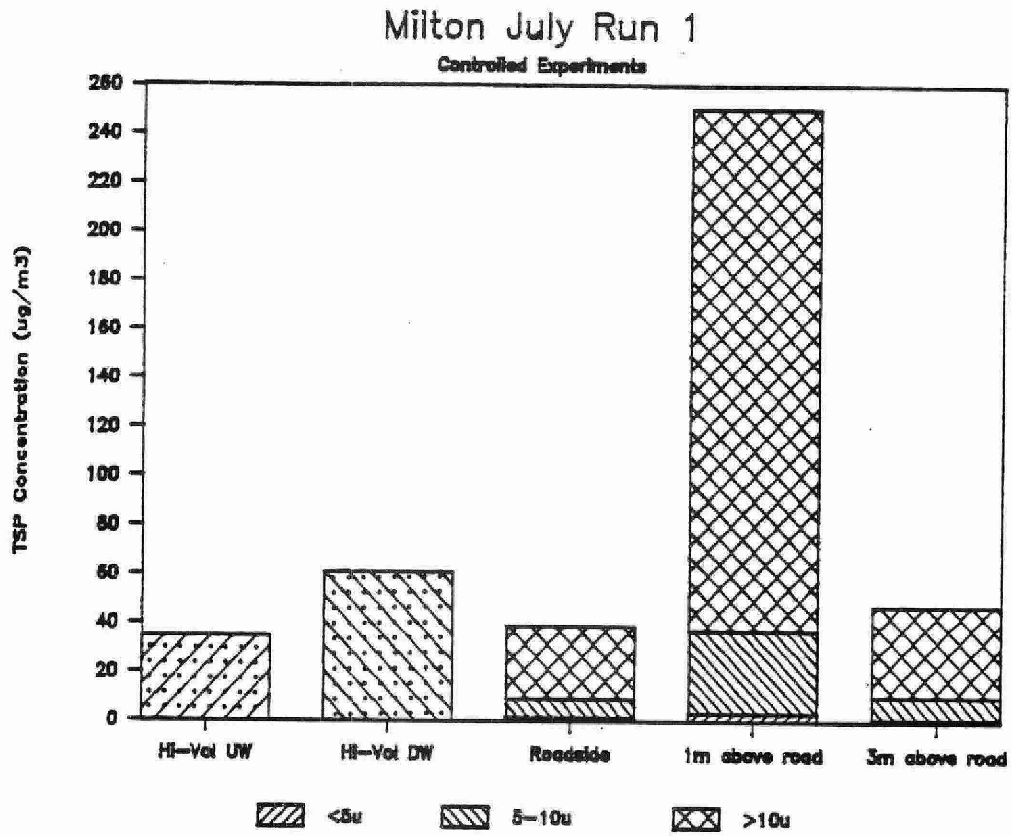


Fig. H 3a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - MILTON, JUNE

ACRES



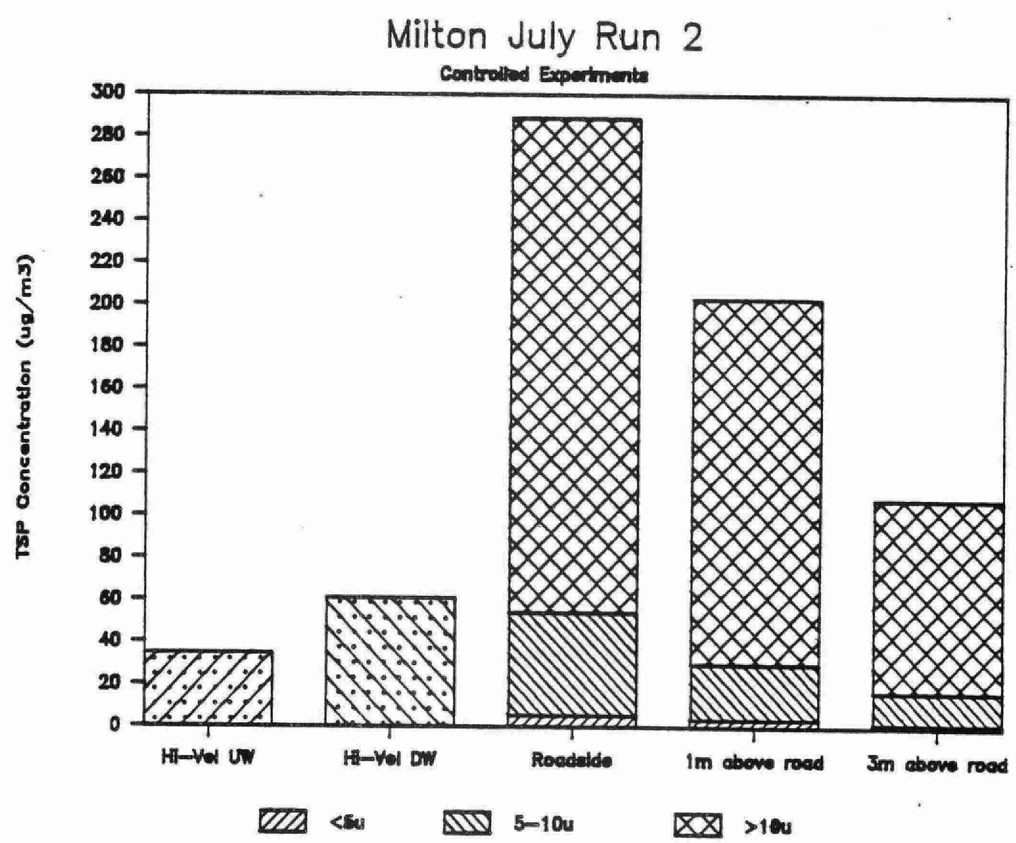
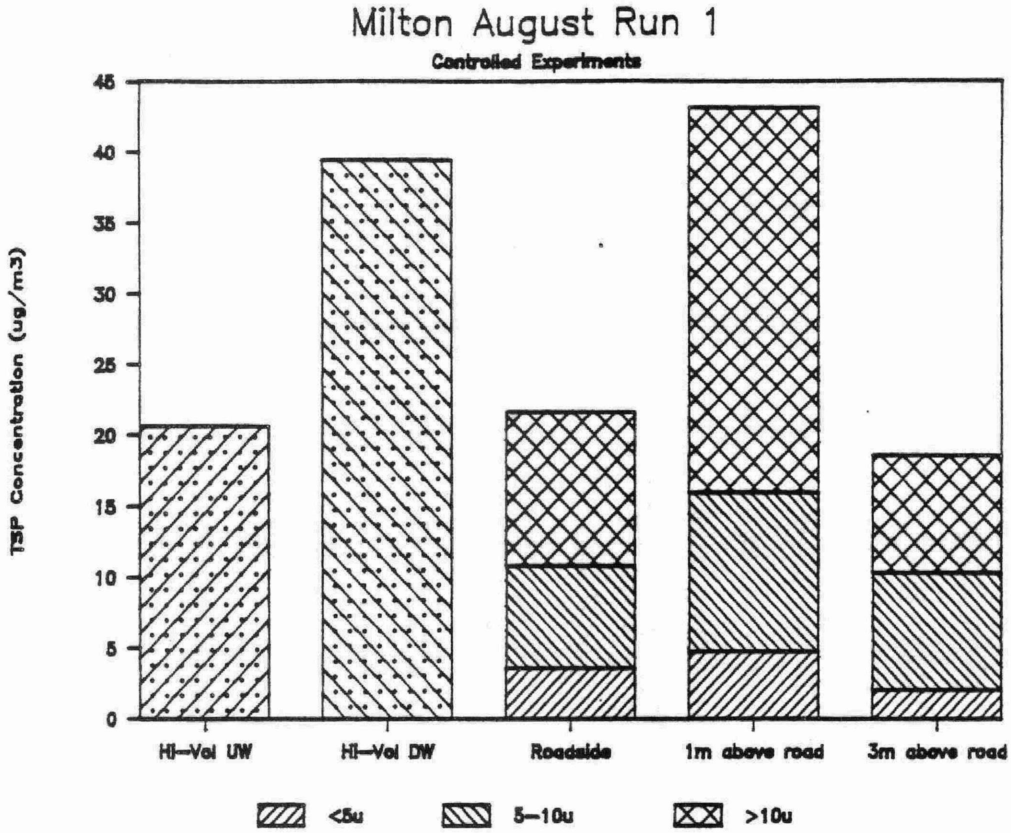


Fig. H 3b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - MILTON, JULY

ACRES



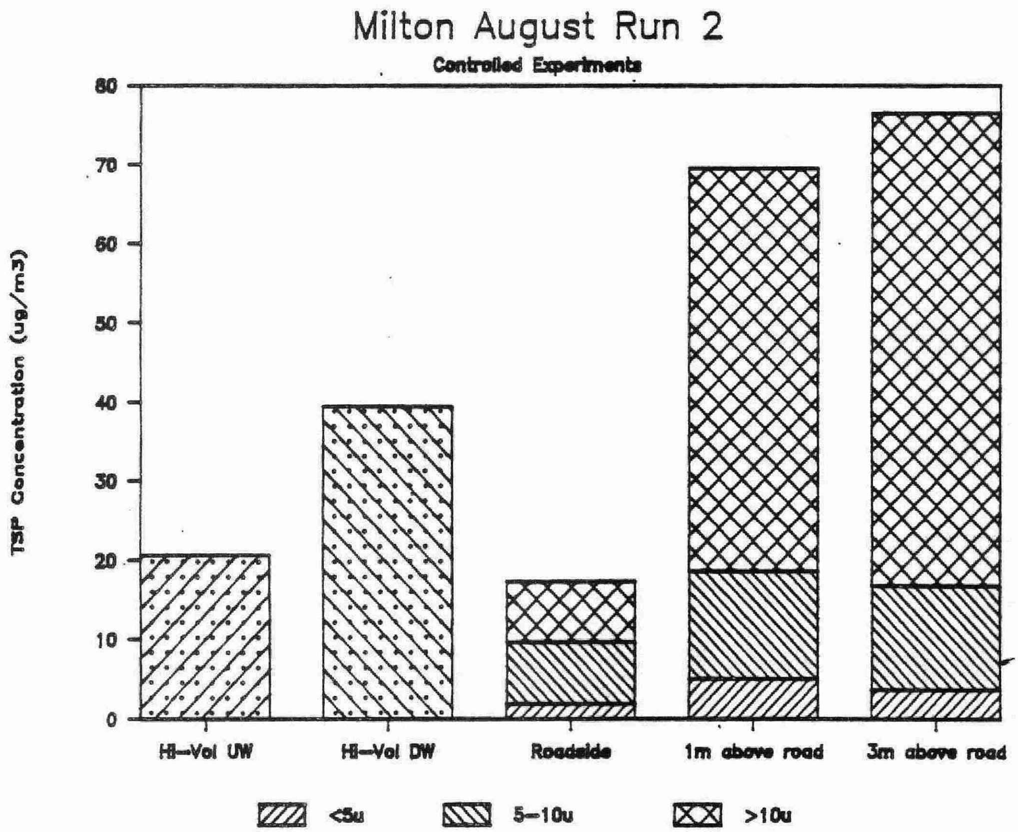
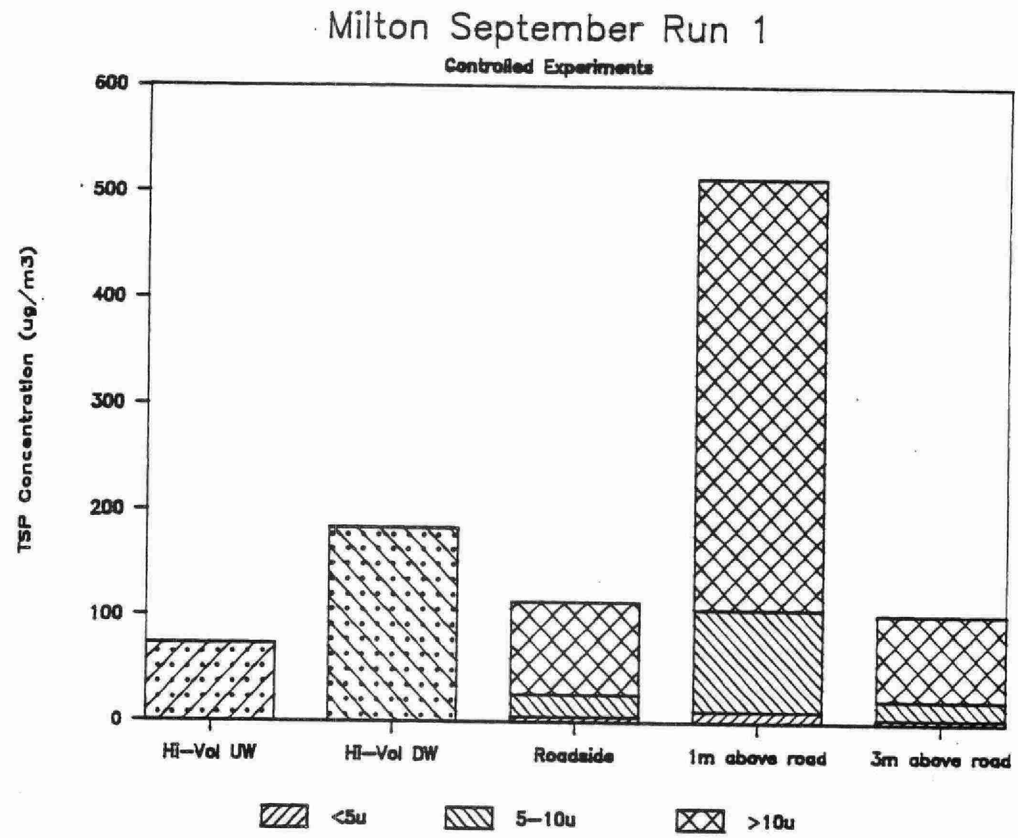


Fig. H 3c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - MILTON, AUGUST

ACRES



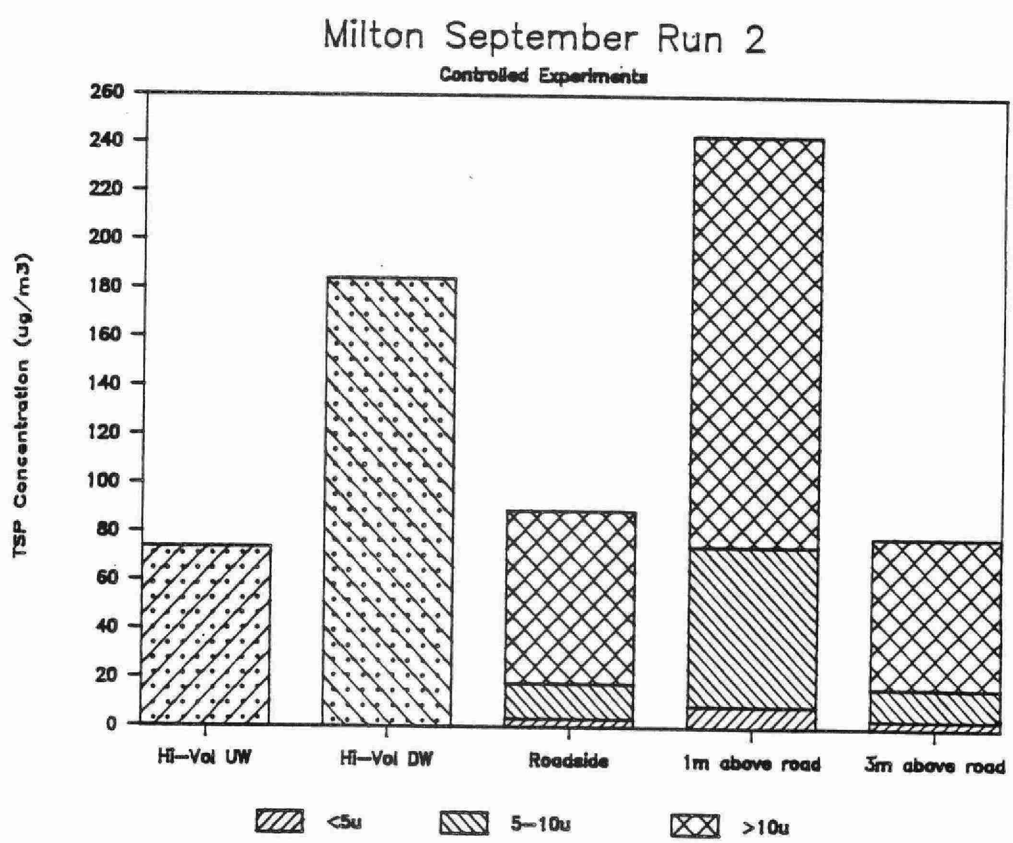
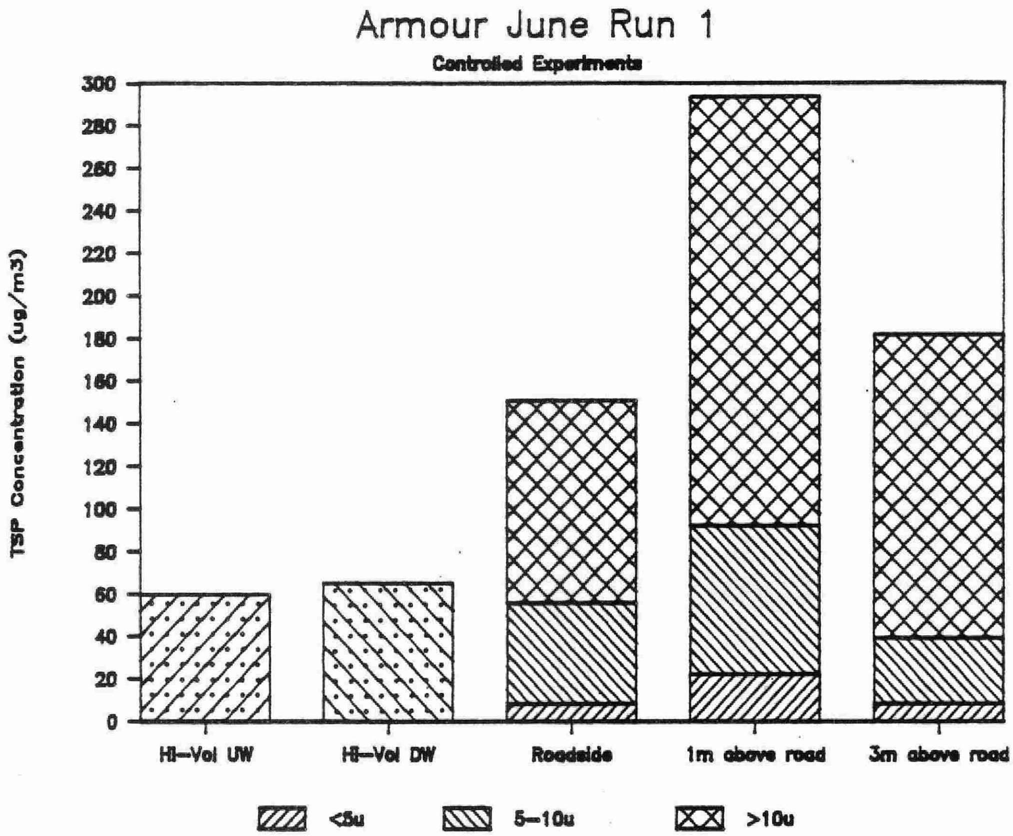


Fig. H 3d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - MILTON, SEPTEMBER



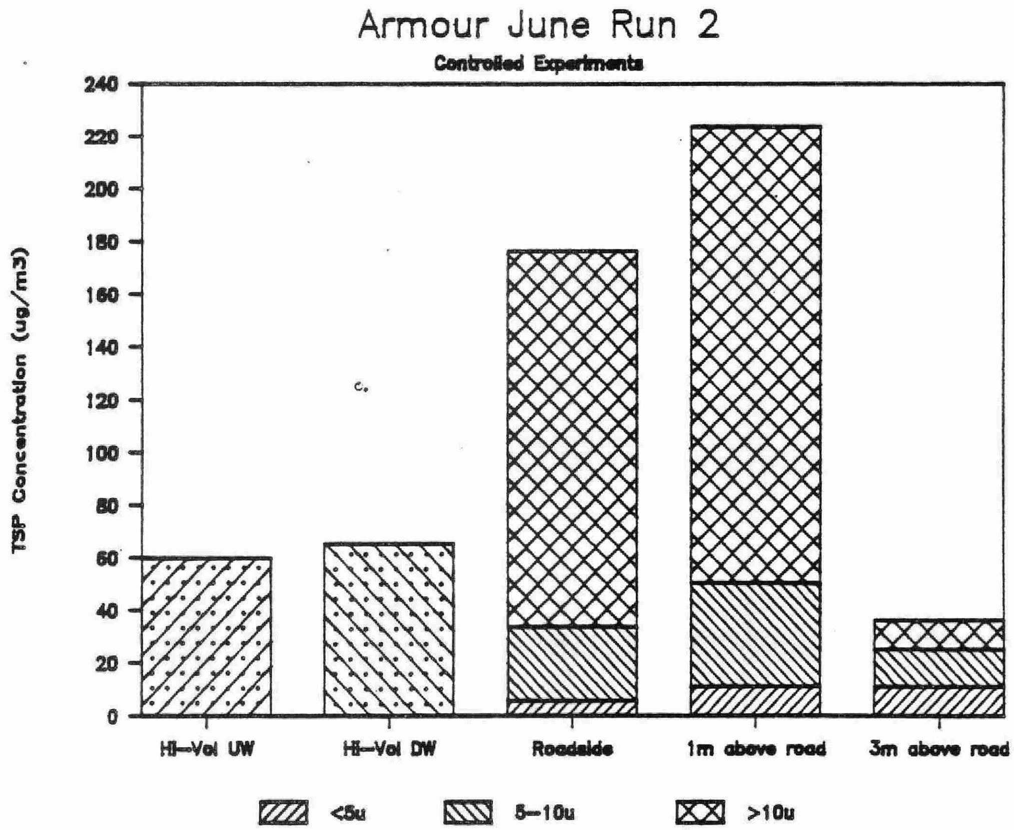
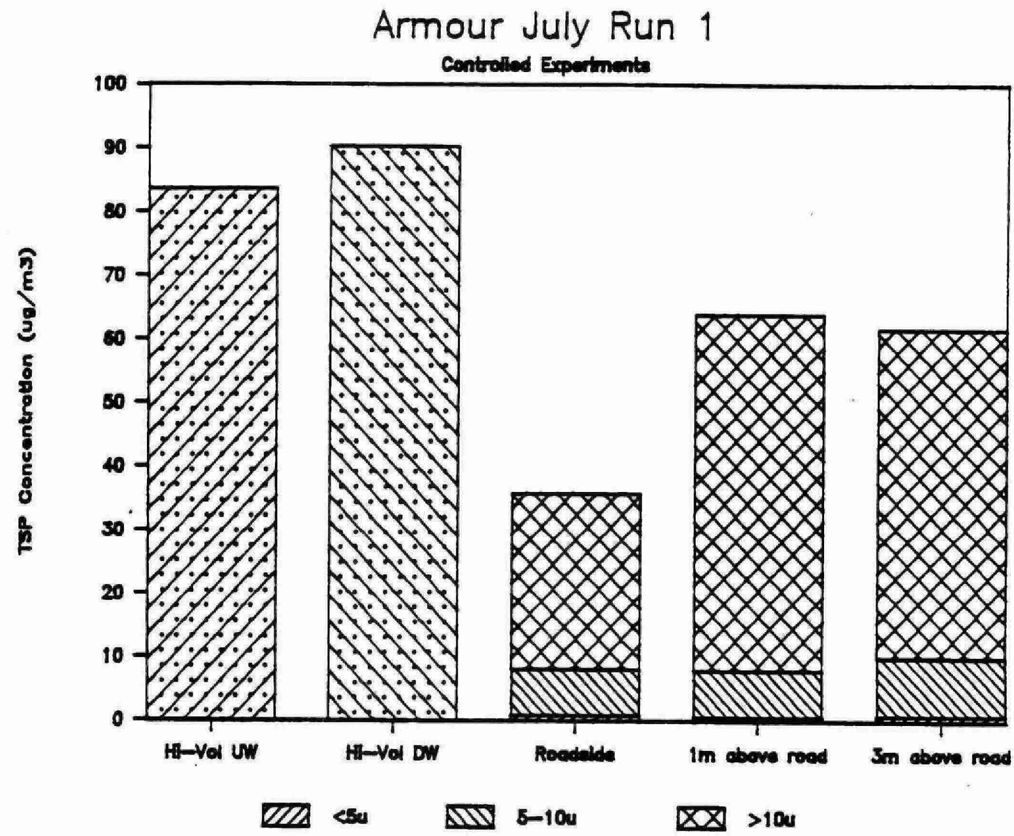


Fig. H 4a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - ARMOUR, JUNE

ACRES



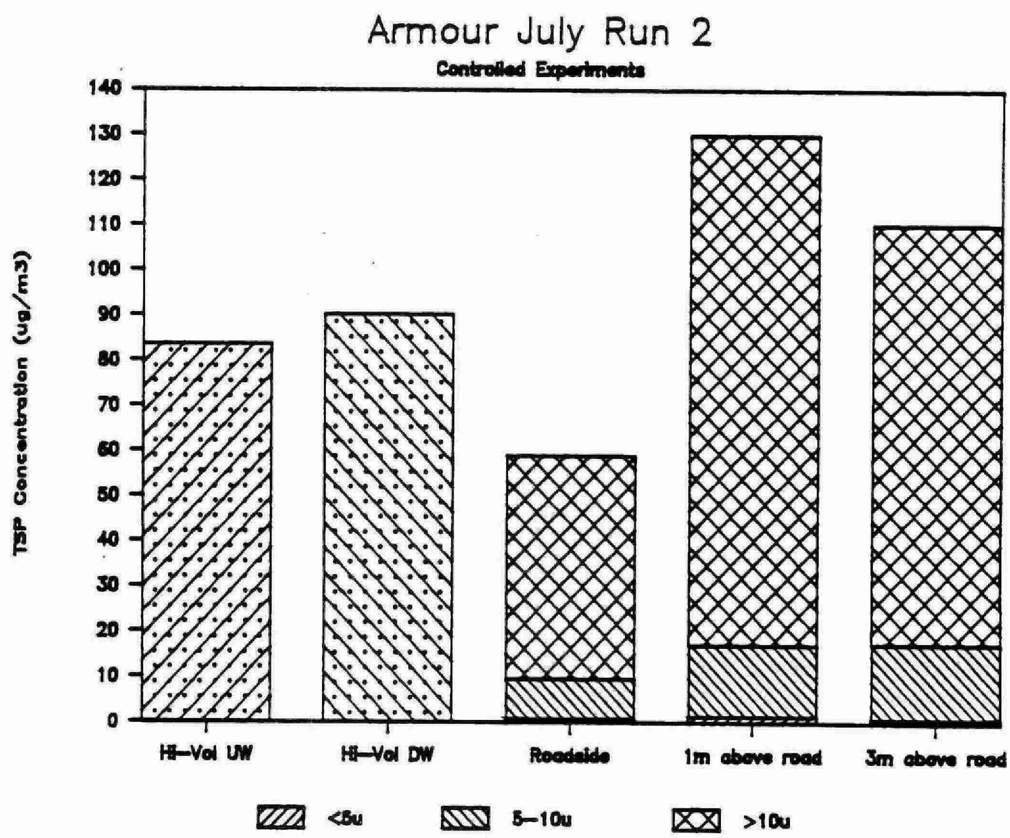
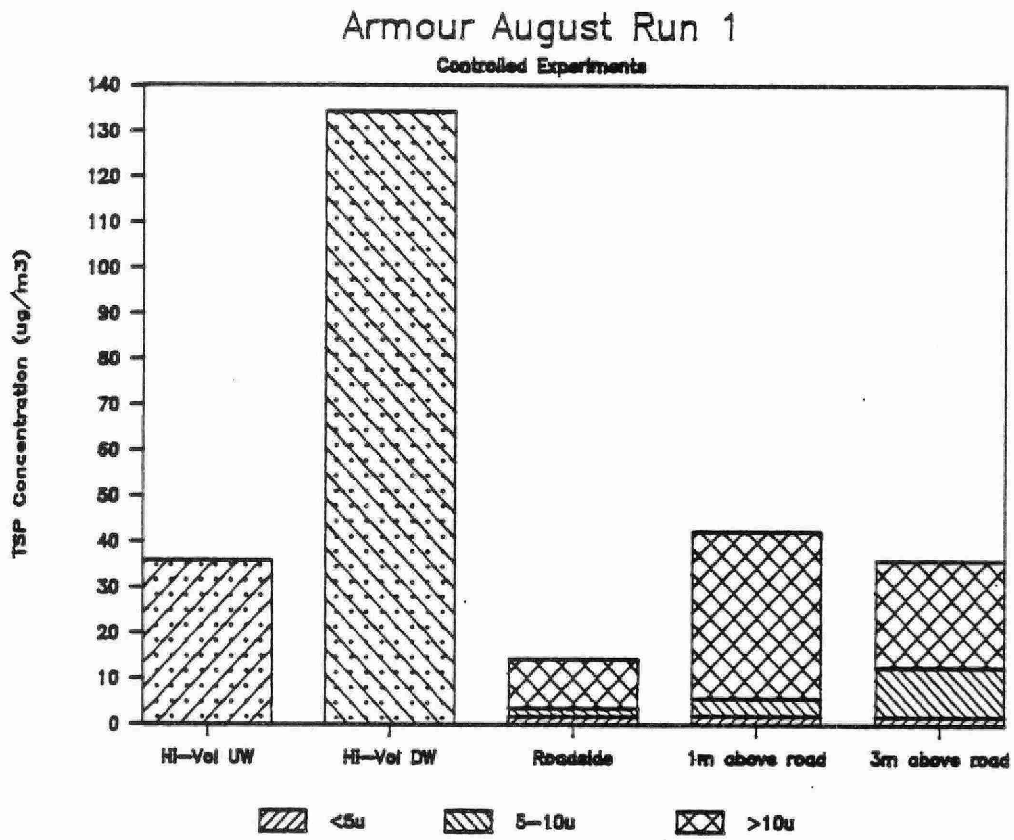


Fig. H 4b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - ARMOUR, JULY

ACRES



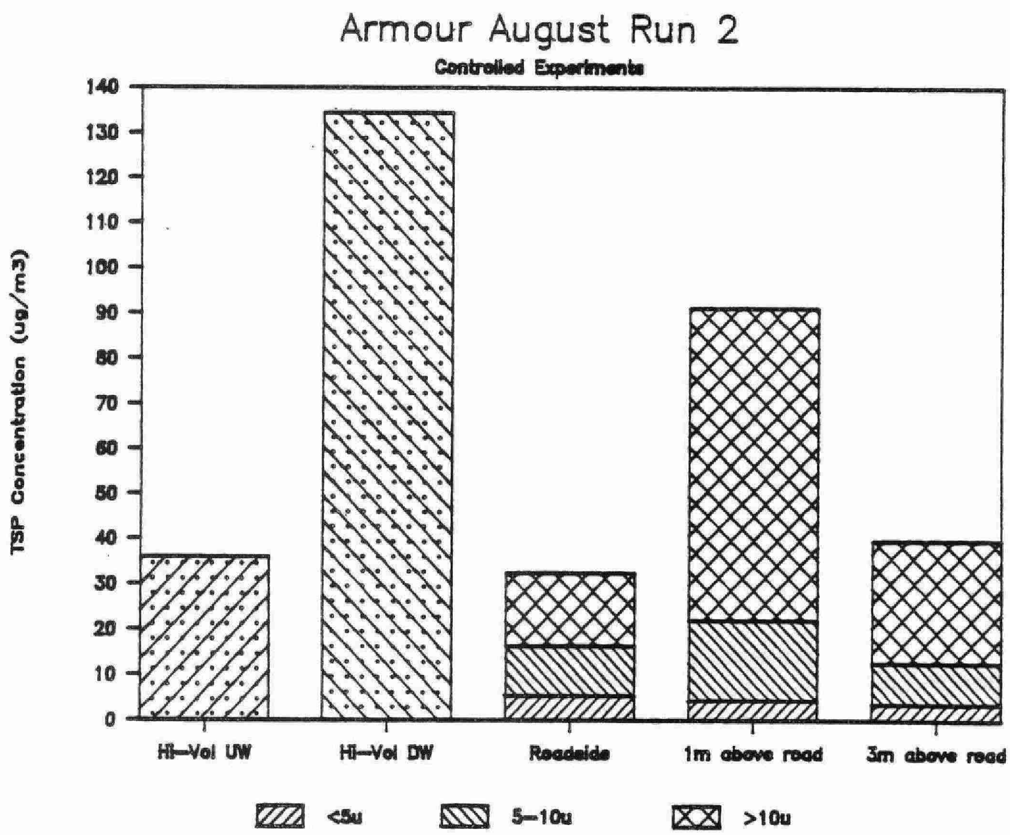
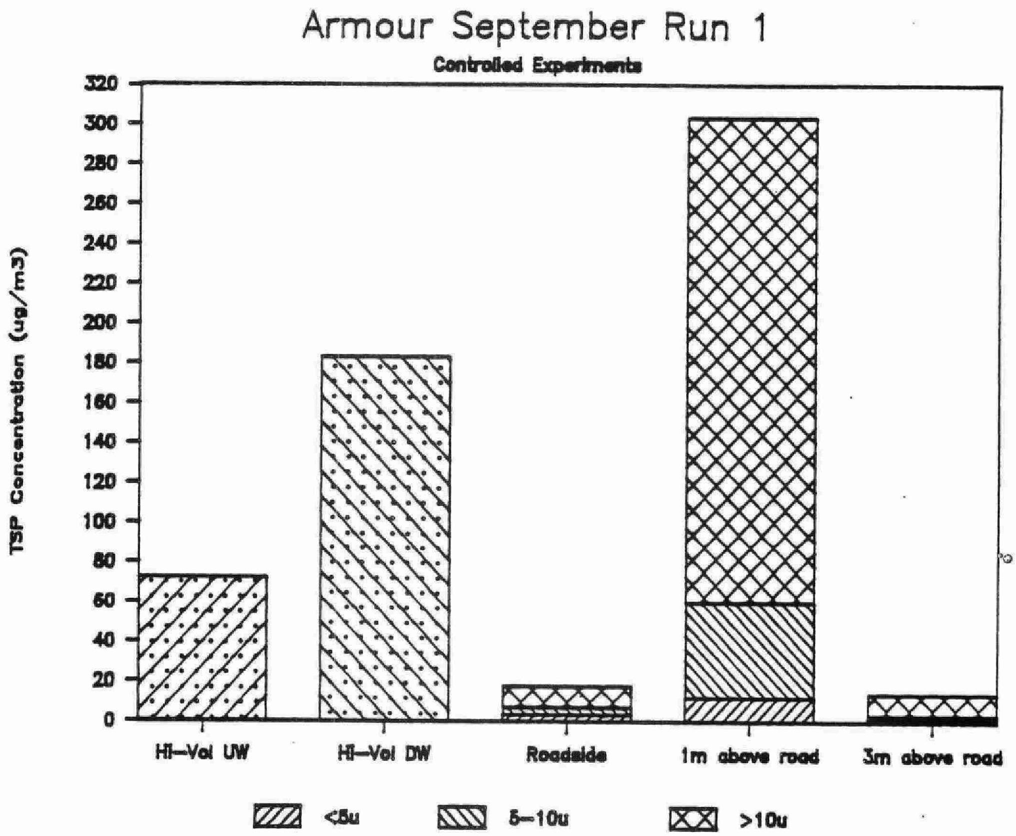


Fig. H 4c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - ARMOUR, AUGUST

ACRES



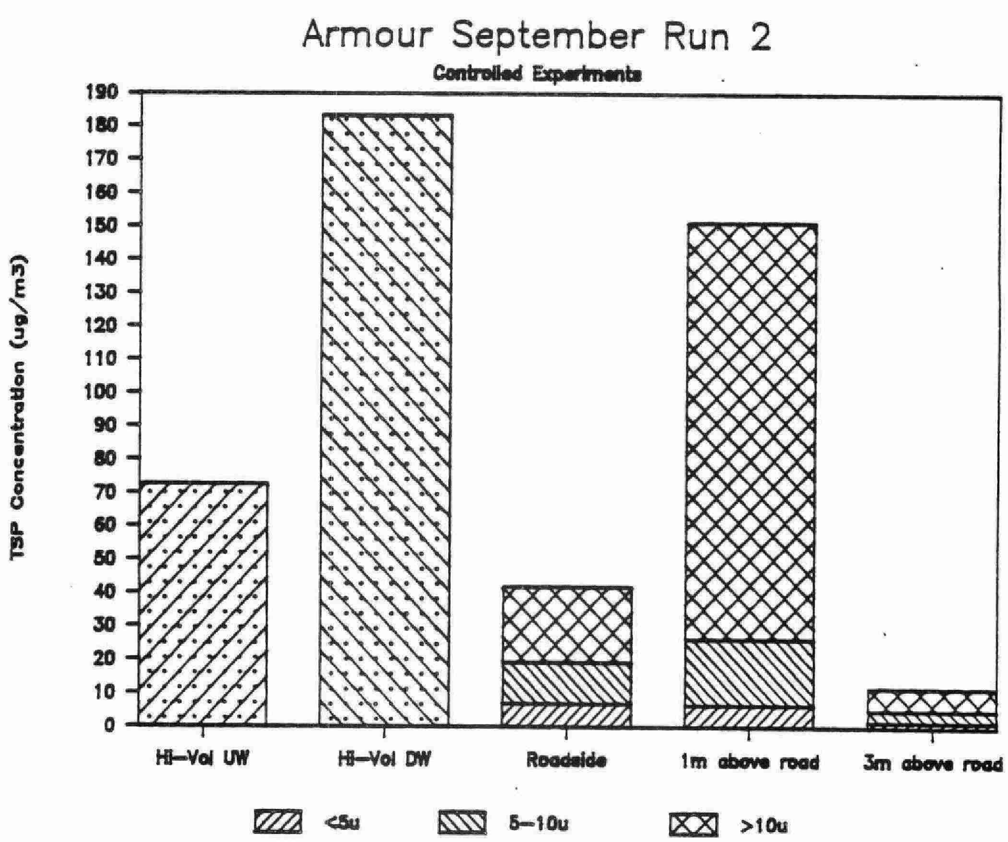
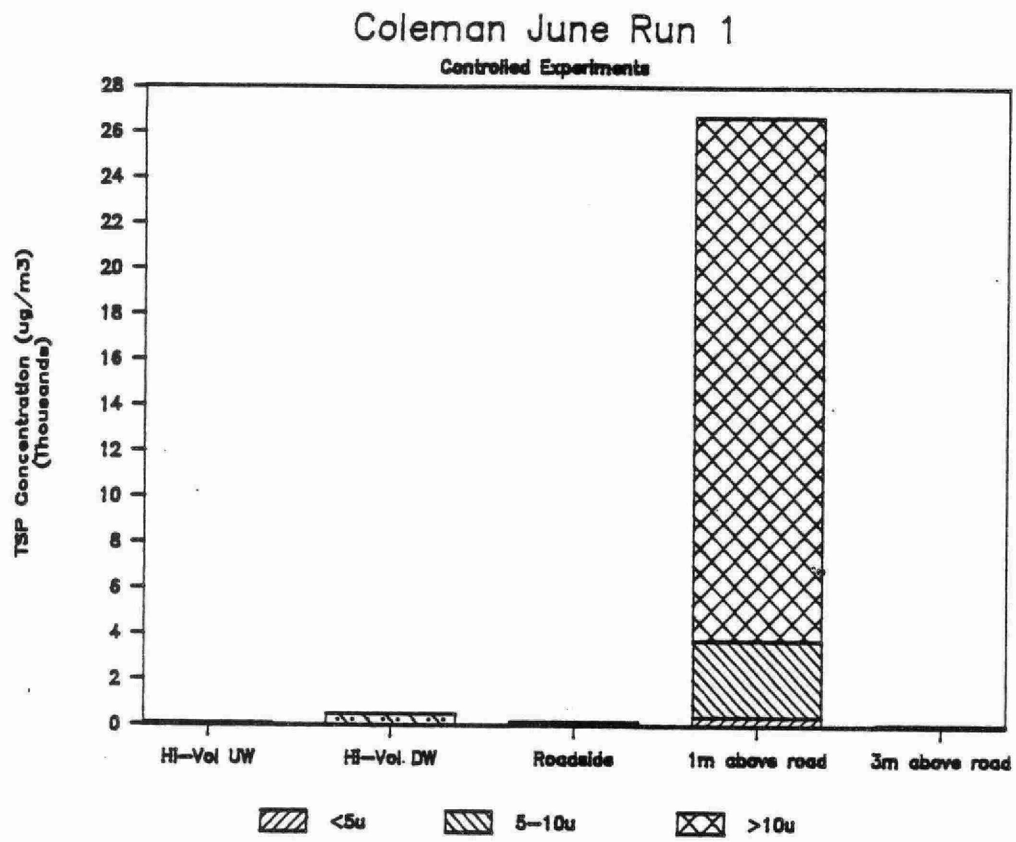


Fig. H 4d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - ARMOUR, SEPTEMBER



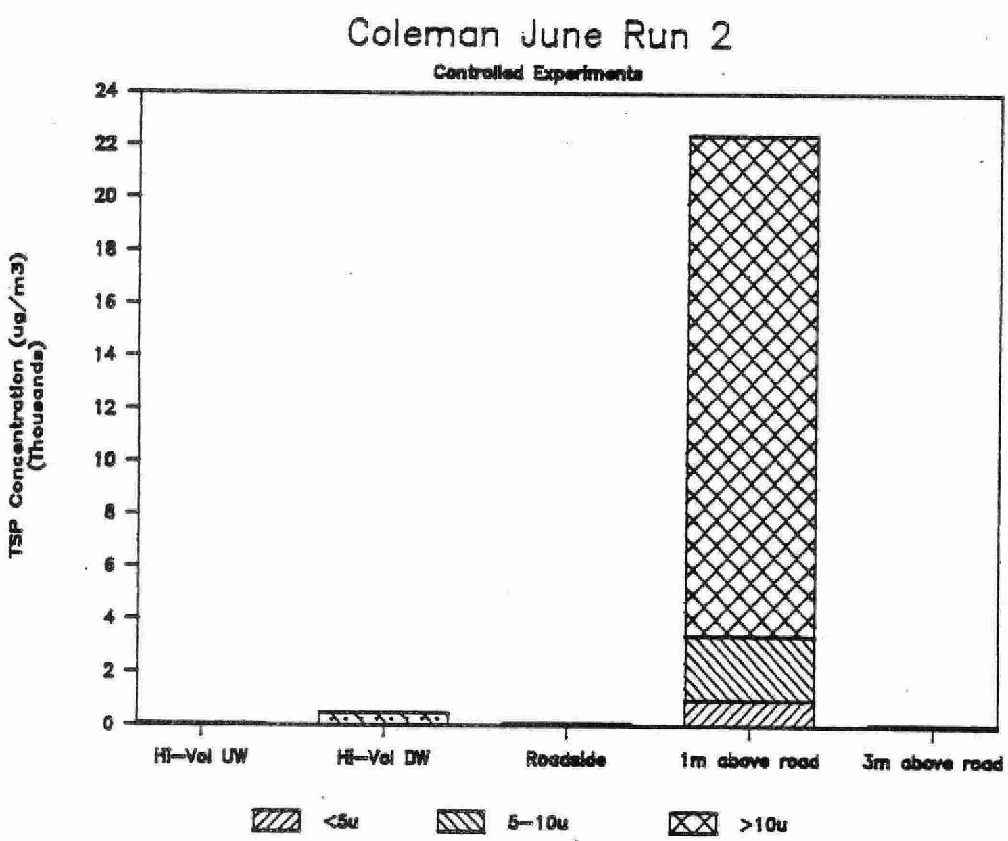


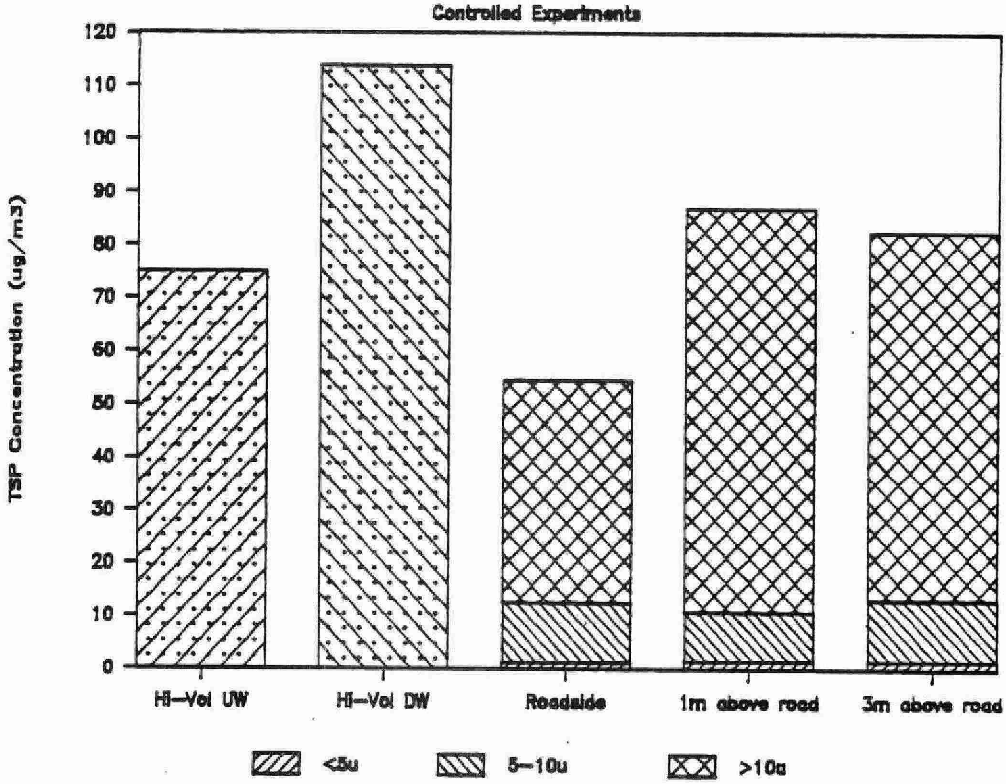
Fig. H 5a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - COLEMAN, JUNE

ACRES

Coleman July Run 1

Controlled Experiments



Coleman July Run 2

Controlled Experiments

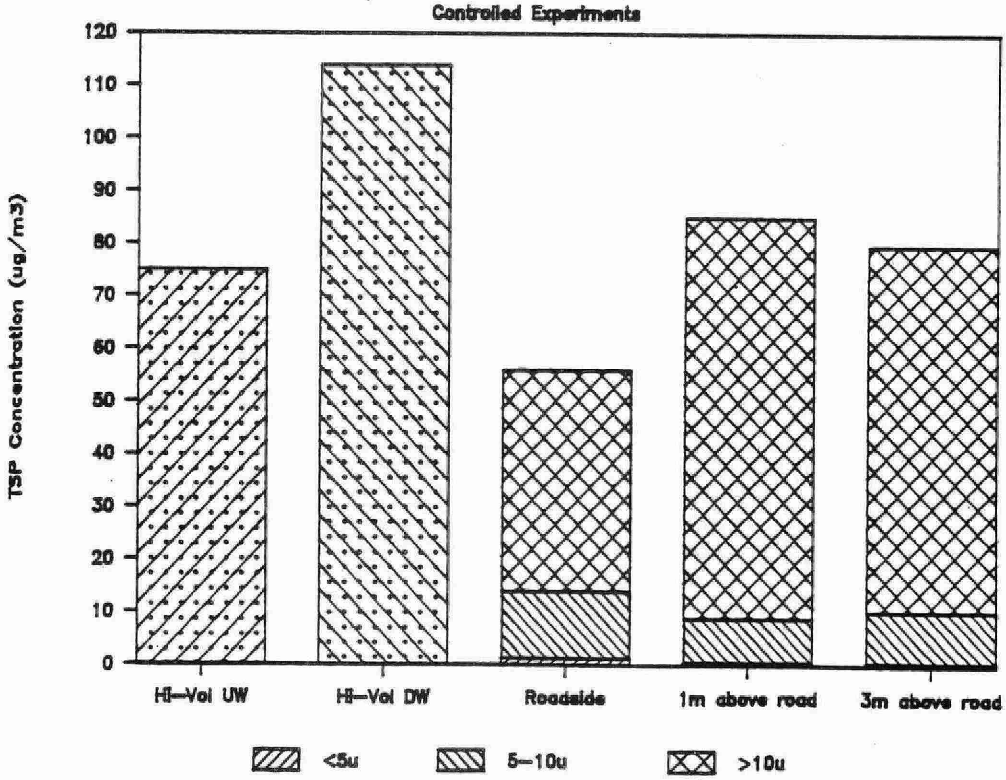
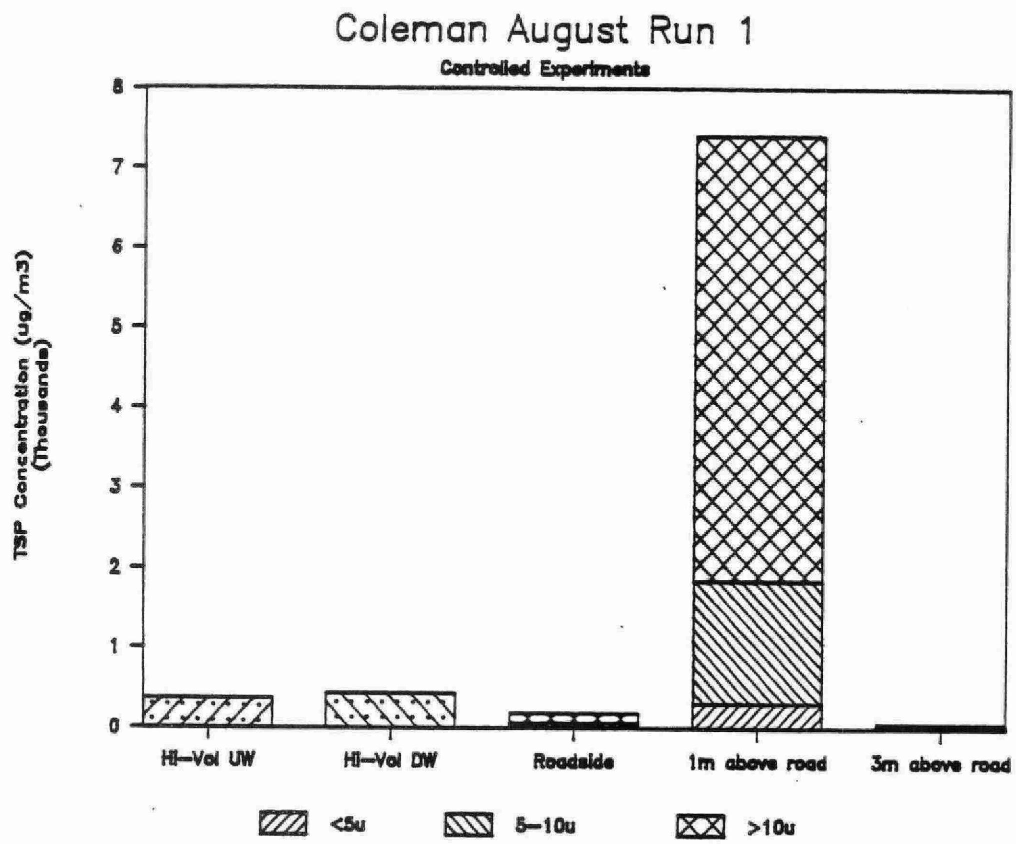


Fig. H 5b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - COLEMAN, JULY



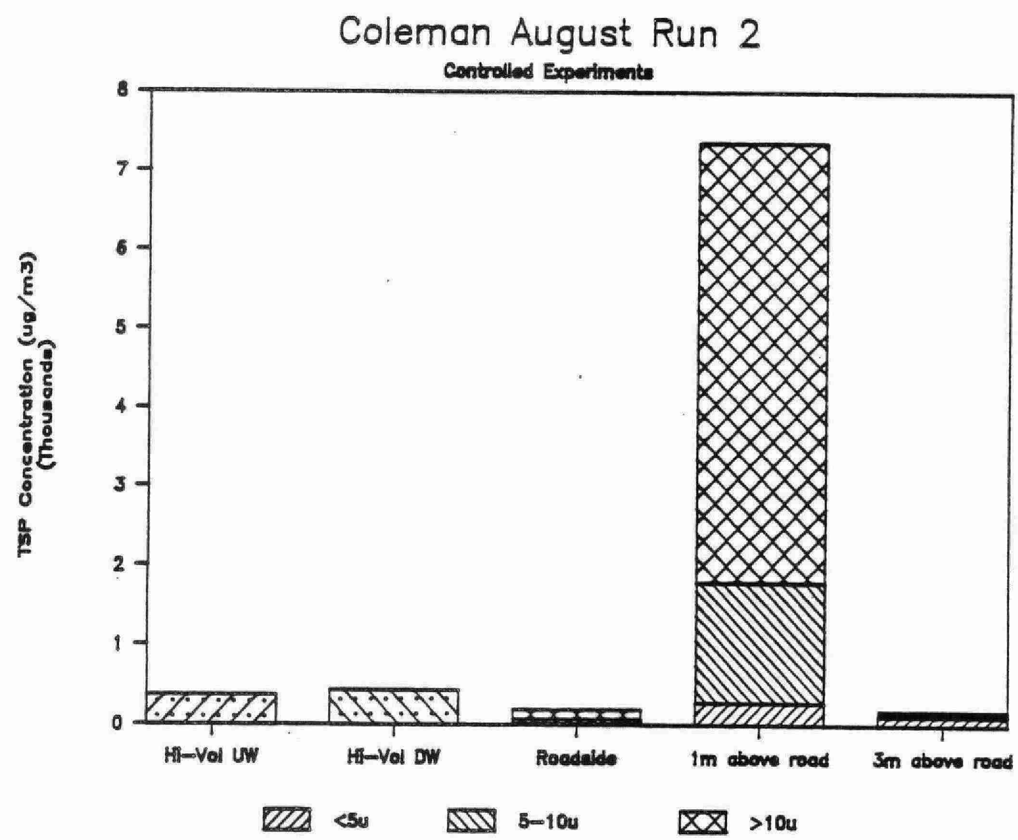
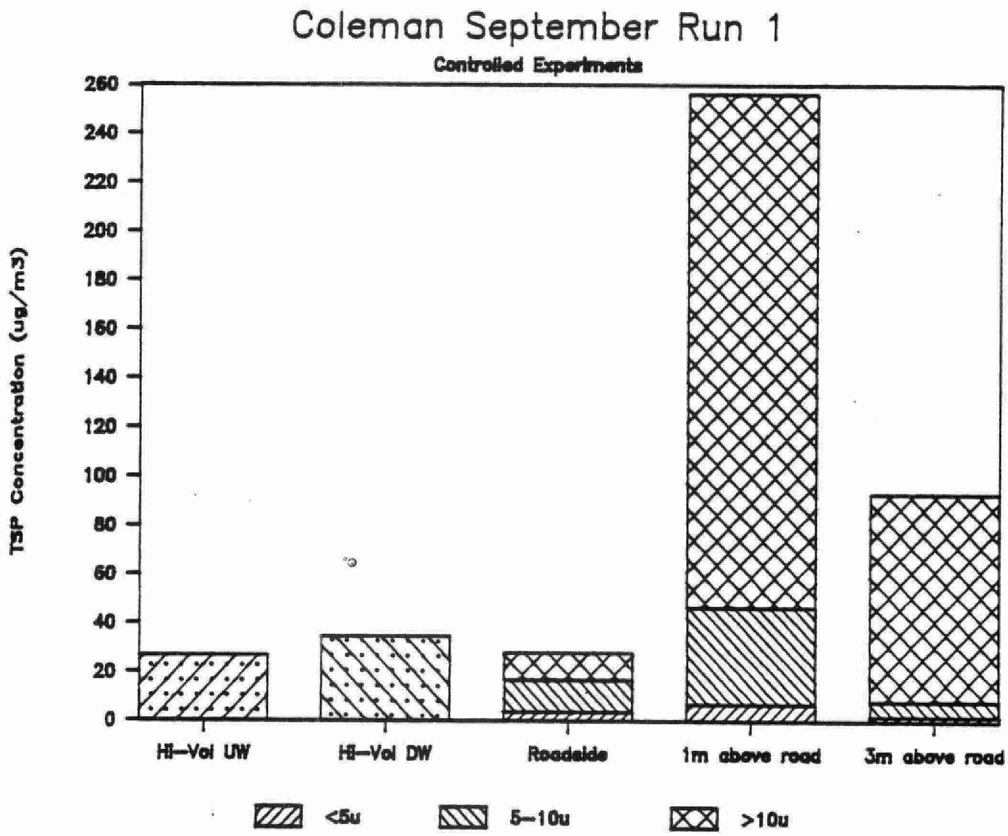


Fig. H 5c

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - COLEMAN, AUGUST

ACRES



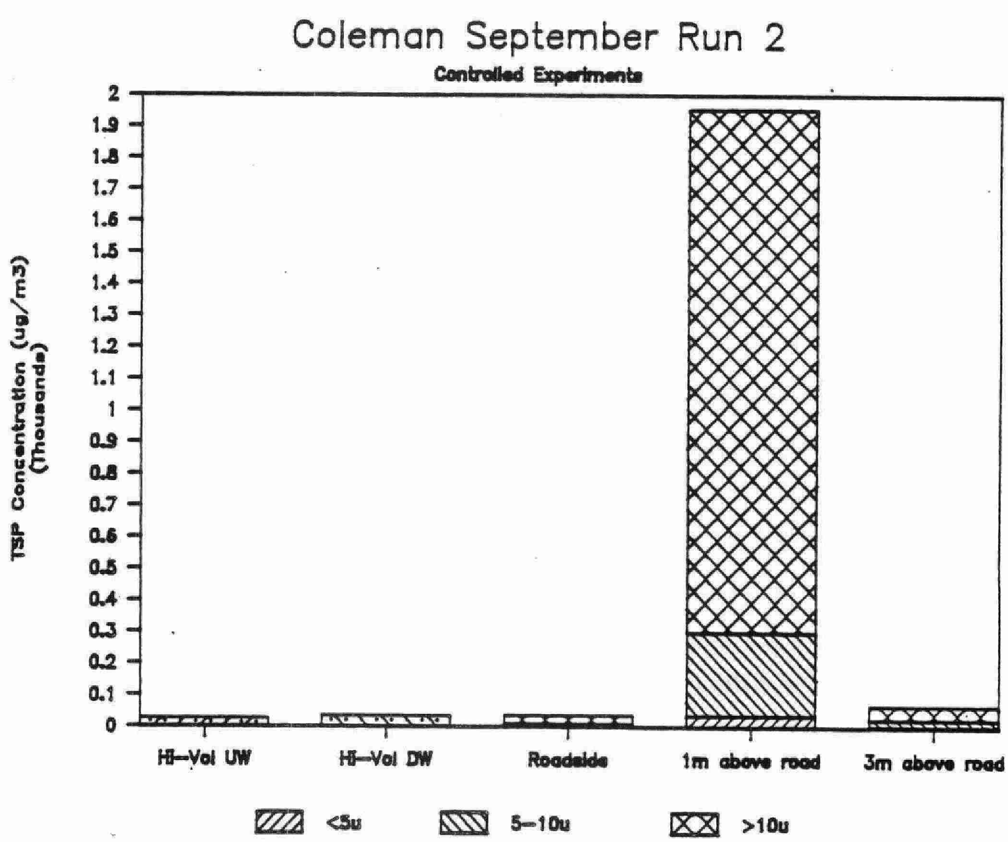
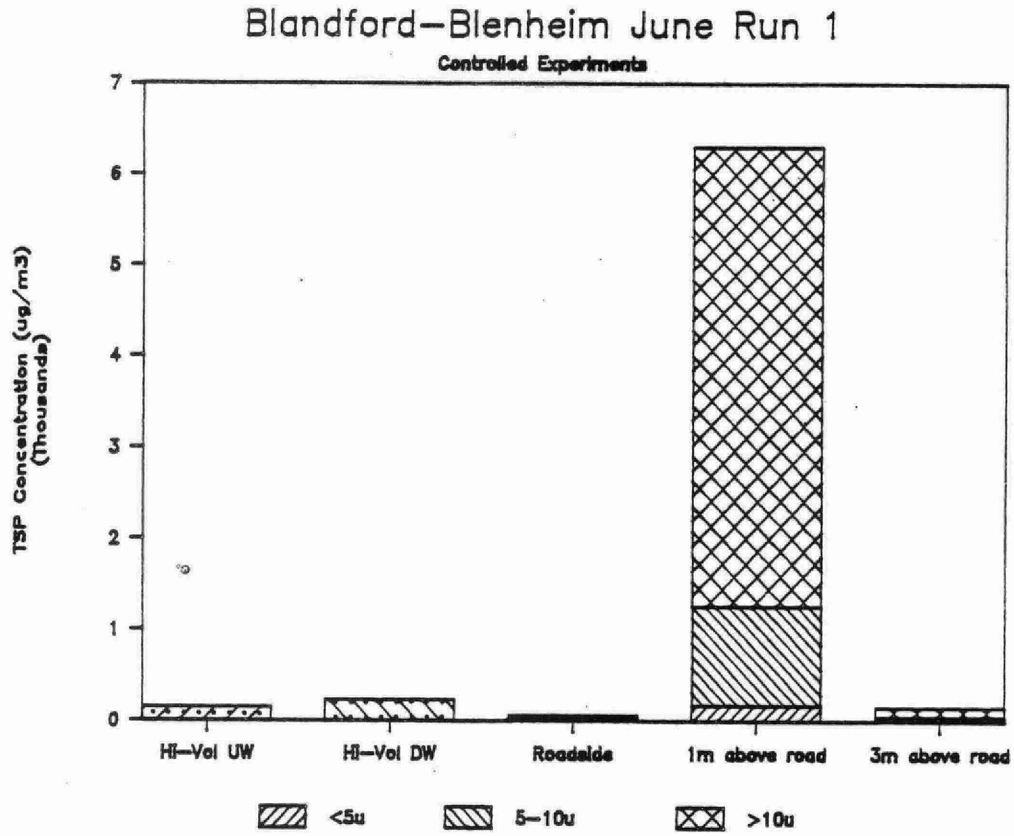


Fig. H 5d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - COLEMAN, SEPTEMBER

ACRES



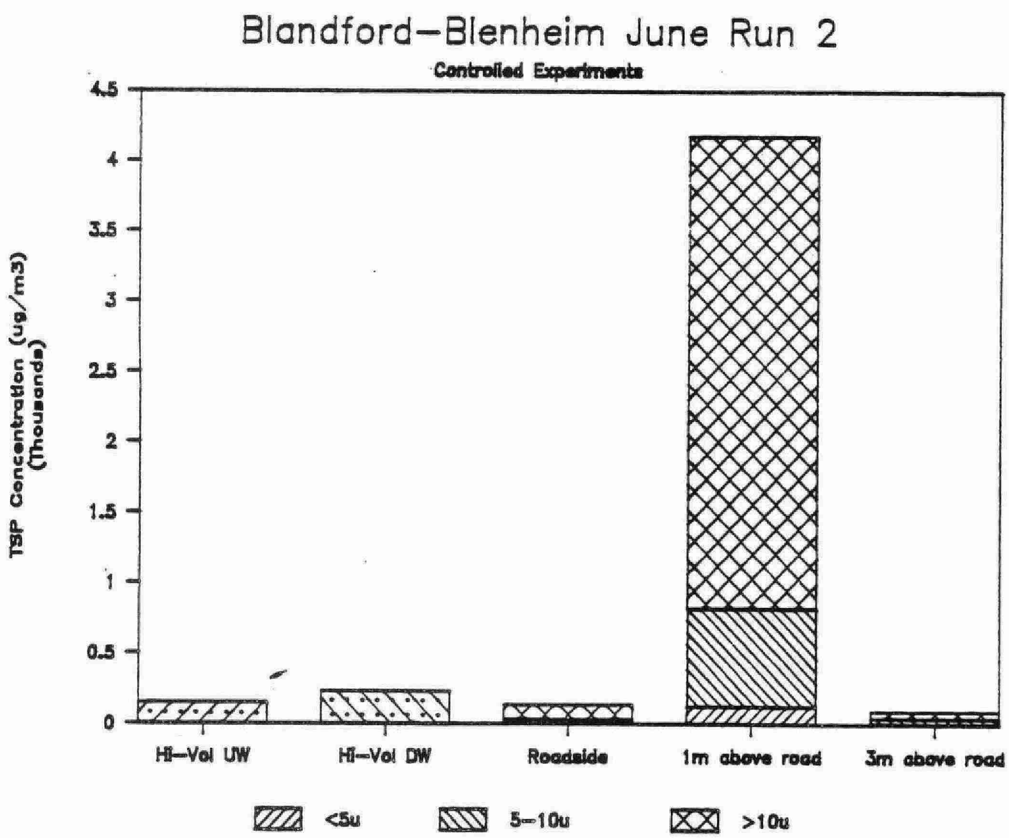
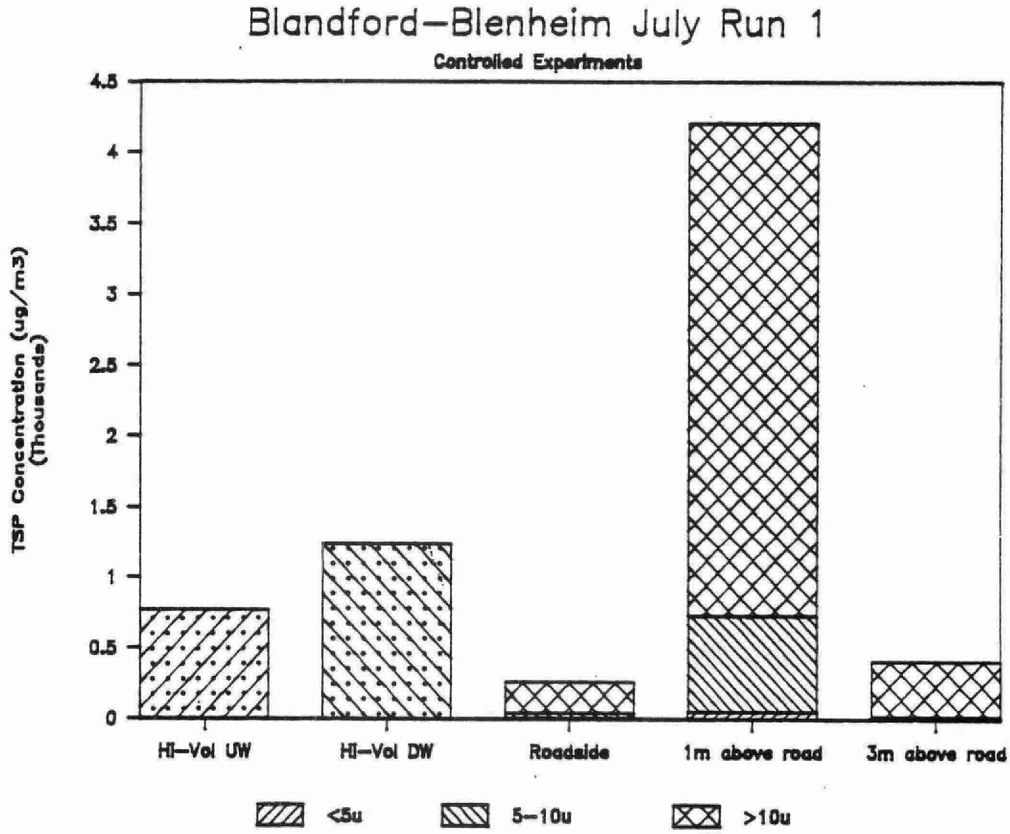


Fig. H 6a

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY
CONTROLLED EXPERIMENTS - BLANDFORD-BLENHEIM, JUNE

ACRES



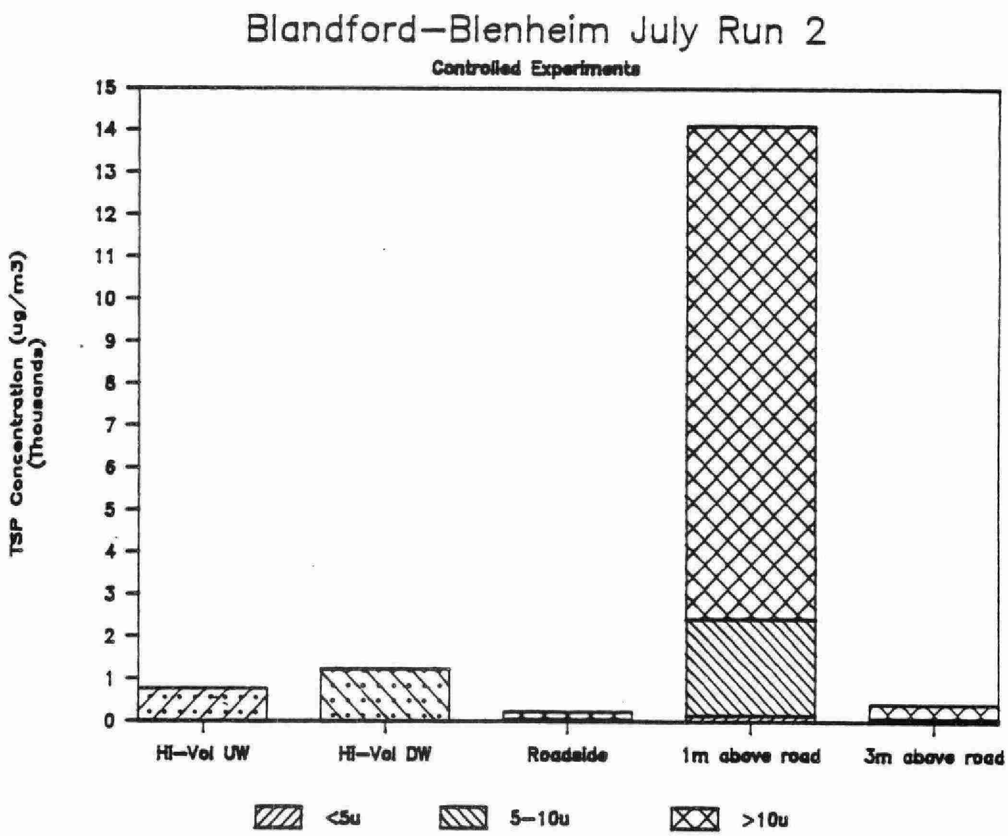
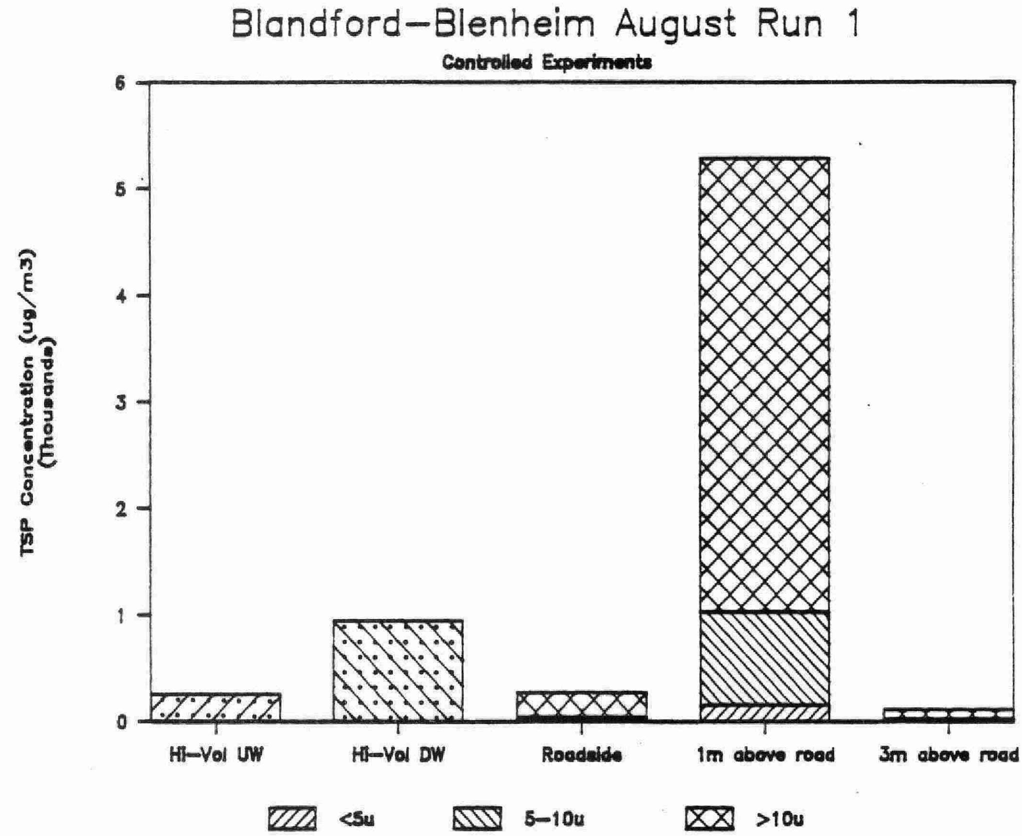


Fig. H 6b

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - BLANDFORD-BLENHEIM, JULY

ACRES



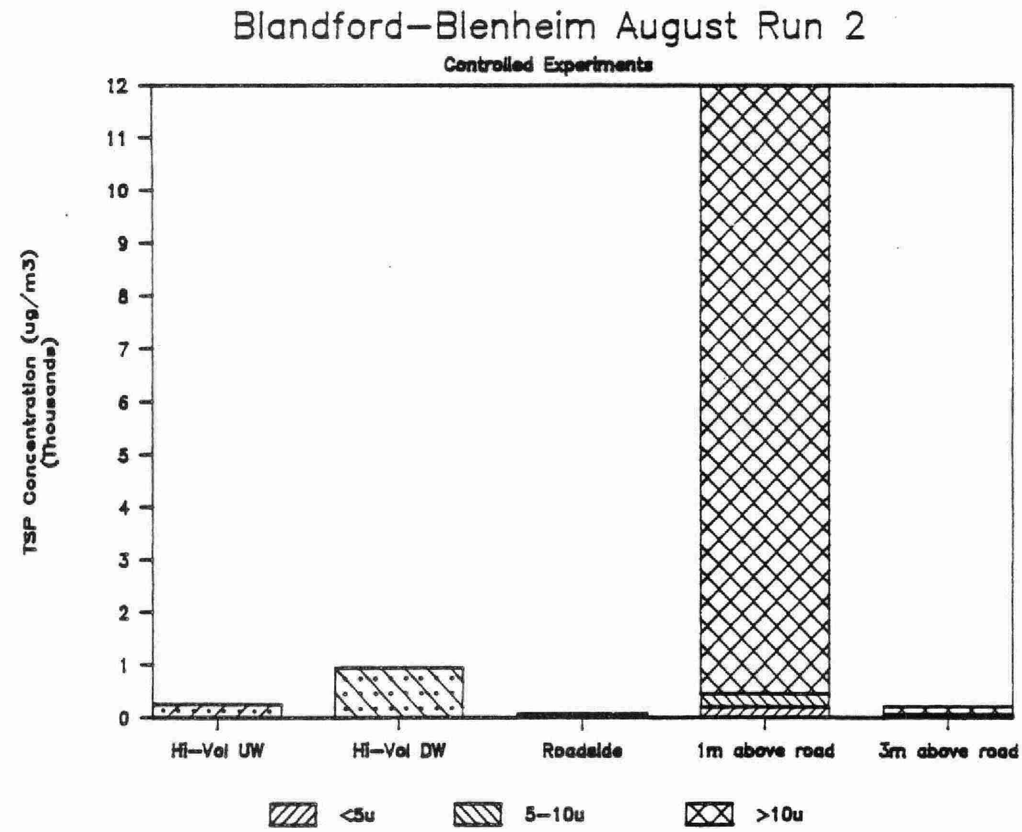


Fig. H 6c

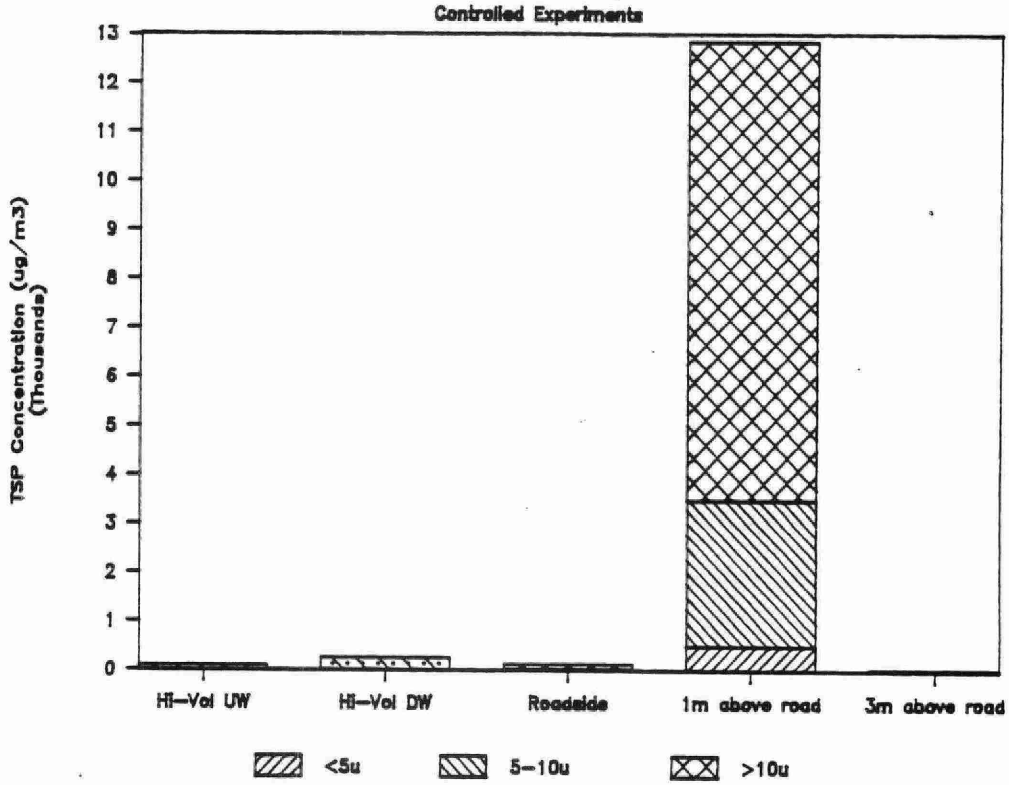
ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - BLANDFORD-BLENHEIM, AUGUST

ACRES

Blandford–Blenheim September Run 1

Controlled Experiments



Blandford–Blenheim September Run 2

Controlled Experiments

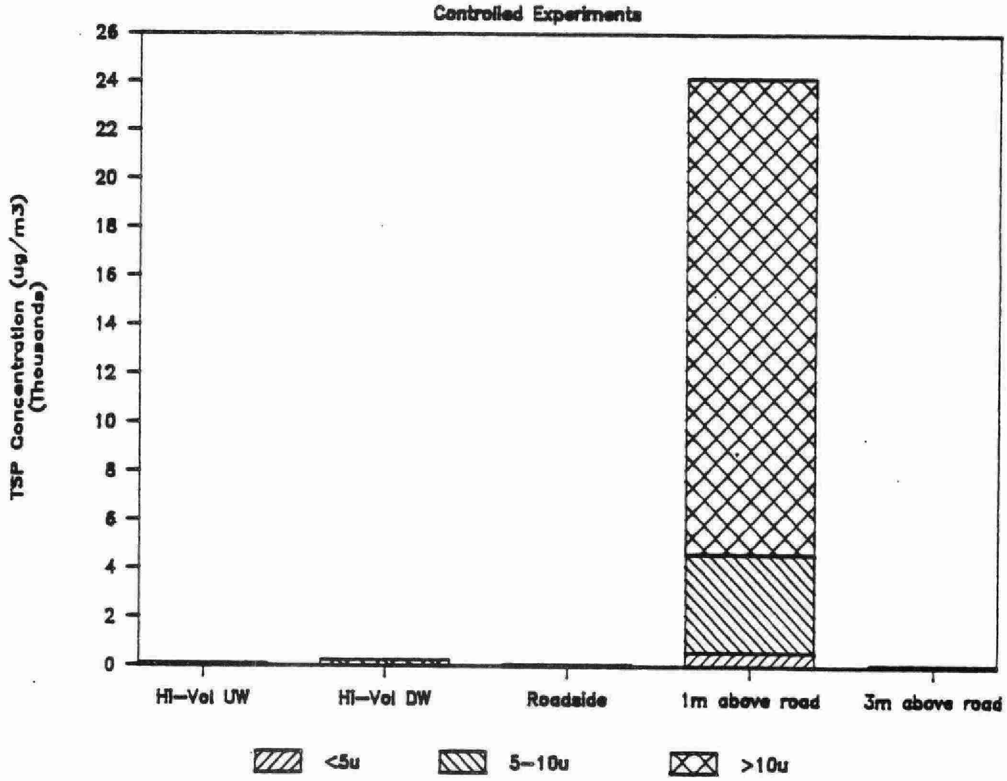


Fig. H 6d

ONTARIO MINISTRY OF ENVIRONMENT
DUST SUPPRESSANT STUDY

CONTROLLED EXPERIMENTS - BLANDFORD-BLENHEIM, SEPTEMBER

APPENDIX I

SURVEY QUESTIONNAIRE AND SUMMARY OF RESPONSES

SURVEY SUMMARY

QUESTION	MILTON	NOTL	HALLOWELL	COLEMAN	ARMOUR	BLANDFORD-BELNHEIM
PART A						
Suppressant Used	Waste Industrial Oil	Calcium Chloride	Pulping Liquor	Teabind	Crankcase Oil	Salt Brine
Total treated road	90 km	55.7 km	31.87 miles	21 miles		189 miles
Suppressant used (years)	6	16	12	2 yrs teabind CaCl2 before		5
Last application before May/87	May/86	Aug/87	April 30/87	May/86		May/87
Appl. rates May - Oct 1987	0.2 - 0.25 gal/sy	May/87 - 4 tons/mile Aug/87 - 4 tons/mile	11300 litres/3 miles spread 8 - 10'	$50.00/ton spread 4 - 6 tons/mile	June/87 1000 gal/mile - 8' width	16m3/mile 16' width
Grading dates and practice	Graded May prior to appl. of dust layer	July/87 Scarify and shape	No dates - Depends on condition and hardness grade 3 passes	Grading not required after sup. appl.		
Application frequency (/year)		Calcium twice a year	Weekly - depends on weather. Cover all roads in spring. Spot in summer	One application	One Application	1
Grading frequency (/year)		Grading as required	Depends on weather. Wet summer - twice/month. Dry - once/mon or 6 weeks	No grading		
Last stone addition Stone addition frequency	1981 As necessary	Spring 1987 Every three years	Sept Mar, late summer	4 years ago every 4 years		May 27/87 Once

SURVEY SUMMARY

QUESTION	MILTON	NOTL	HALLOWELL	COLEMAN	ARMOUR	BLANDFORD-BELNHEIM
PART B						
Suppressant Cost (Cost/unit) Transportation cost	$0.81/gl delivered included in sup.	$243.20/ton Transportation and appl.	Free Self Applied	$50/ton applied	$0.75/gal applied	$18.67/m3 Applied
Type of vehicles used	2000 gal or 4000 gal units with pumps	Tanker and spray bar	Tandem with 2500 gal tank	Tanker Trucks		Tractor trailer
Time vehicles used for sup.	unknown		Complete coverage 7 days Spotting 3 days/week	Applied by cont.		Contract
Price of vehicle	unknown		Tank - $500.00	Unknown		Contract
Life expectancy of equipment	unknown		Tank 25yrs - Truck 15yrs	Unknown		Contract
Maintenance costs of equipment used for sup. application	unknown		Cleaning washdown Paint tank every 2 years	Unknown		Contract
Manhour costs and skill level	unknown		18.92/hr - 3 trips/day Moe Ontario Reg 309 Special permit and MOE drivers licence			Contract
Staff lost due to contractor	unknown	No significant time loss		No		Contract
Benefits or cost due to the suppressant chosen	Reduced grading to one application/year		Excellent binder - does not require humidity. Cheaper than CaCl2. Grading cut in half.	Maintenance reduced Dust control improved		

SURVEY SUMMARY

QUESTION	MILTON	NOTL	HALLOWELL	COLEMAN	ARMOUR	BLANDFORD-BELNHEIM
PART C						
Who selected the suppressant used and why		Town. See CaCl2 below	Council. Impressed with evaluation	Council- Superior product		Road Superintendant Cost
How is contractor or supplier selected	Restricted to CAN-AM OIL since they confirm material approved by MOE Concerned with integrity of supplier	Price review.	Happy with Bontar will continue to use as long as possible	Product available from only 1 contractor		Invitation Price
Comments on various Suppressants						
Calcium Chloride	Won't last complete seas. Require extra application than oil. One application less expensive.	Easily applied. Arrective Can be graded between applications and consolidates the granular base	Too expensive. Requires humidity.	Costs - Temdust lasts longer		Efficient Expensive
Waste crank case oil		Environmental problems. Need assurance oil safe. Can't grade after applied Slippery if tracked on pavement. Damages cars.	Environmental problem. Need to cold patch potholes. Unable to grade properly. Slippery when wet - dangerous.	Envrionmental		Environment
Waste industrial oil	Use this material	Same as above	Same as above.	Envrionmental		Environment
Pulping liquor	Dilute solution and strong odor	Not familiar with	Good environmentally.	Not familiar with		?
Tembind	Did test section in 1984 Unsuccessful but would try again	Not familiar with	Unknown	Presently using		?
Bond-All	no knowledge	Not familiar with	Unknown	Not familiar with		?
Salt brine	dilute solution doesn't hold for long periods	Not familiar with	Unknown	Not familiar with		Cost (no - effect)
Coherex	no knowledge	Not familiar with	Unknown	Not familiar with		?

PART A - SCHEDULE APPLICATIONS OF DUST SUPPRESSANT

1 - How many miles or kilometers of treated road are under your jurisdiction?

2 - How long have you applied that suppressant to the test section of road?

3 - When was the last application before May 1987?

4 - Please give dates and application rates of the suppressant during the period May to October, 1987. If you quote the rate in tons per mile or kilometer, please state width of application.

5 - Please give dates of grading of the road surface from May to October 1987. Briefly describe grading practice.

6 - What is the average frequency of application and grading of the road?

7 - When was stone last added to the road? How often is it necessary to add stone?

PART B - COSTS OF APPLICATION

This section will permit the comparison of suppressant costs on a $/km basis. If application is by contractor, please complete the appropriate questions and include the contractors name, address and the name and telephone number of the individual you deal with.

1 - Suppressant Costs

Please give cost per unit for suppressant showing the transportation cost separately.

2 - Equipment Costs

What types of vehicles are used for suppressant application?

What fraction of the time are these vehicles used for suppressant versus other purposes.

Describe approximate price, life expectancy, and maintenance costs for equipment used exclusively for suppressant application (e.g. sprayers, tanks, etc.)

3 - Manhour Costs

Describe the skill level and appropriate manhours required for suppressant application. If the application was performed by a contractor, could permanent or part-time staff be lost?

4 - Other Costs

Describe any other benefit or cost due to the suppressant you have chosen. For example, is there any impact on maintenance, etc.

PART C - OTHER INFORMATION

1 - Who selected the suppressant you use? Why?

2 - How is the contractor/supplier selected; that is, do you review various products or select on the basis of price for a specified product.

3 - Please comment briefly on the dust suppressants listed below. Tell us why you would or would not use them. For example, cost, efficiency, environmental problems, availability, or lack of information. We are interested in both facts and opinions.

Calcium Chloride
Waste crank case oil
Waste industrial oil
Sodium carbonate pulping liguor
Tembind
Bond-All
Salt brine
Coherex